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ABSTRACT

This instructional packet deals with biology, soil ecology, and specific farming practices that promote sustainable agriculture. It focuses on different types of life in the soil, the interactions that occur, and how proper tillage and nutrient management can enhance and develop beneficial soil life. The instructional materials are designed to make the important link between science and agriculture and to provide hands-on experiences that enable students to understand how the science-based subject matter included affects agriculture. Self-contained background information, activities, and visual masters are included. The individual instructional exercises can be used independently by both agriculture and science teachers or can be effectively team-taught. Unit topics include: exploring the underground community soil life, the foundation of soil health and food production, investigating the role and importance of fungi in the soil, recognizing the importance of bacteria in recycling of soil nutrients, understanding the role of more complex soil organisms, and application of the relationship between soil organisms, soil health, and plant growth. (JRH)

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ED 388 519

Unit II
The Living Soil

*** Have Fun**
***Think Career**
***Learn to Manage Underground Livestock**

Exploring Inner Space

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Table of Contents

Page

Project Contributors iii

Curriculum Background and Instructions v

Ordering Form for Living Soil Curriculum viii

Introduction 1

Unit II-a
Exploring The Underground Community 13
Soil Life: The Foundation of Soil Health and Food Production

Unit II-b
Discovering the "Weavers" of the Soil: Soil Fungi. 47

Unit II-c
Recognizing the Importance of Bacteria in Recycling of Soil Nutrients 71

Unit II-d
Understanding the Role of More Complex Soil Organisms 95

Unit II-e
Willy's Tour Comes to a Close
Application of Relationships Between Soil Organisms, Soil Health, and Plant Growth. 123

Unit II References 141

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Curriculum Background and Instructions

Organization of Materials

Whether we are in the city or on the farm it is important that we make good land and water management decisions. Decisions must be made that balance production with profits. Unit II (Subunits a through e) provides an in-depth look at the soil community through its organisms. It will enhance the innovative approach Unit I provided in teaching basic principles of soil biology. Unit II will take you on a tour of the 'underground' world with "Willy" the worm as your guide, demonstrating that we can be progressive in producing food in our gardens and on farms, while at the same time driving benefit from soil life as 'underground livestock'. This unit, developed during 1993 and 1994 is made available to teachers and educators in 1994. Following is a short summary of each of the Subunits:

Introduction
Several group activities (including case studies) set the stage for: *Where Have We Been in Unit I and Where are We Going in Unit II*.

Unit II-a
Exploring The Underground Community
Soil Life: The Foundation of Soil Health and Food Production
Participants will be introduced to various types of soil life and the roles they play in soil fertility and sustainable agriculture through "hands on" activities.

Unit II-b
Discovering the "Weavers" of the Soil: Soil Fungi
Participants will investigate the role and importance of fungi in the soil. The symbiotic relationship between fungi and plant will be highlighted.

Unit II-c
Recognizing the Importance of Bacteria in Recycling of Soil Nutrients
Participants will observe living bacteria and investigate their relationship to other organisms in the soil and soil health.

Unit II-d
Understanding the Role of More Complex Soil Organisms
Participants will investigate characteristics of soil insects and how they improve the soil. The nematode will also be highlighted, and it's beneficial role in plant growth.

Unit II-e

Willy's Tour Comes to a Close

Application of Relationships Between Soil Organisms, Soil Health, and Plant Growth. A wrap-up with activities and laboratories designed to combine concepts learned in Unit IIa - IId and some of Unit I. The activities will emphasize the "team approach" - when bacteria, fungi, insects, nematodes, etc. work with each other.

Flexibility in Use

Unit II of the Living Soil curriculum enhances what has already been taught in the previous unit by expanding on the different types of life in the soil, the interactions that occur, and how proper tillage and nutrient management can enhance and develop beneficial soil life. The instructional materials are designed to make the important link between science and agriculture. They provide more "hands-on" exercises, thereby enabling participants to better understand how the science-based subject matter in Unit II affects agriculture.

This curriculum accommodates teachers in it's flexibility. It can be used as a whole unit, or utilized one section at a time.

Self contained background information, activities, and visual masters are included. The individual instructional exercises can be used independently by both agriculture and science teachers, or can be effectively team-taught. Unit II can open opportunities for exploration while taking a more in-depth look at soils.

The laboratory exercises are appropriate for both rural and urban people. Even though **Agriculture's Impact on the Living Soil Video Tape** was used in Unit I, it is designed as an interest approach in Unit II, along with activities related to the underground community and the "team" of soil organisms.

Competencies

Many of the competencies included in the instructional exercises address the Iowa Department of Education's new vocational competencies. Refer to *Vocational Instructional Occupational Competencies*, included in this unit. They are listed as follows:

1. Describe basic soil biology principles
2. Define the role of earthworms and microbes in the soil.
3. Analyze the environmental impact that agricultural practices have on the soil.

4. Explain the impact has on natural resources and the environment.
5. Analyze/interpret information to make sound management decisions.
6. Follow directions.
7. Utilize equipment correctly.
8. Handle hazardous chemicals and flammable materials correctly.
9. Explain limiting factors of successful plant/crop growth.
10. Explain the balance needed to maintain land use resources.
11. Identify contemporary natural resources issues and concerns.
12. Use standard units of measure accurately.
13. Organize thoughts and clearly express point of view.
14. Use standard soil survey report.
15. Maintain clean and orderly work area.
16. Work effectively with others.

Format

Background information (including key vocabulary terms) is included for the teacher and can be duplicated for the participants in the form of information sheets (**INFO-MICRO-1**). Case studies are designed to stimulate class interactions, problem solving, and the enhancement of critical thinking skills. Written activities and knowledge builders (evaluation instruments) for participants are contained in activity packages marked (**ACT-MICRO-1**). Laboratory or field exercises marked (**LAB-MICRO-1**) are designed for "hands-on" learning. Visual masters used for transparencies are marked (**VM-MICRO-1**).

Project Background

The **Agriculture's Impact on the Living Soil Video Tape** was funded by the Resource Enhancement and Protection Program (REAP), Des Moines, Iowa, and is incorporated as an interest approach in this curriculum. The balance of the curriculum was funded by the Leopold Center for Sustainable Agriculture, Iowa State University, Ames. The Iowa Association of Soil and Water Conservation District Commissioners (IAWSCDC) supported the development of the curriculum.

LIVING SOIL CURRICULUM

Order Form

		Quantity	***Total***
Unit I	***$12.00***		
Video	***$15.00***		
Unit II	***$12.00***		
Total Package (Unit I, Unit II, and Video)	***$29.00***		
		Grand Total	

Send order and check made out to:

AEMS, Agricultural Education & Studies Department
217 Curtiss Hall
Iowa State University
Ames, IA 50011.

INTRODUCTION

Instructions for Introducing Unit II

The introduction may be considered for one or two class periods.

1. Use **VM-MICRO-1 (Balancing Production with the Environment)** to set the stage for class activity in introducing this unit. Ask participants the following questions:
    - * What does "undercover livestock" mean to you?
    - * If we have responsibility for caring for livestock on the farm, shouldn't we also care for the underground animals working on our behalf?

2. Hand out **INFO-MICRO-1 (Soil Organisms)** for participants to read and to acquaint them with important concepts in managing beneficial soil life. Ask participants to prepare a summary of approximately 200 words on the most important points to remember from this information. (Also ask them to indicate a career from the list that appeals to them, explain why, and how that career would relate to balancing food production with improving the environment.)

3. Hand out and review **Where Have We Been** to prepare participants for the next activity.

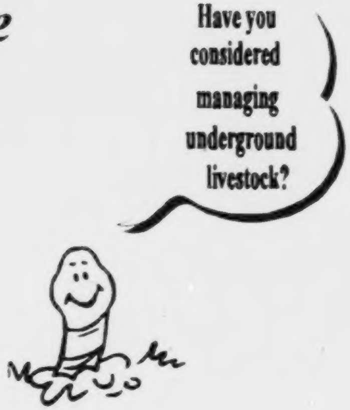
4. Hand out and play the game **Balancing Human Activity with Soil Life**. This game will reinforce practical application of tillage and nutrient management practices and it's impact on soil life.

5. Distribute **Case Study 1 (Land Management with "Undercover" Livestock).** Divide participants into groups to debate the issues.

6. Distribute **Case Study 2 (Your Decisions May Not Be Popular).** Divide participants into groups to debate the issues.

7. Explain to participants that they will be learning about protecting the homes and food of soil life in the units ahead. "Willy" the earthworm will lead us underground introducing us to the "underground livestock and zoo."

Balancing Production with the Environment


Have you considered managing underground livestock?

Whether we are in the city or on the farm, it is important that we make good land and water management decisions. Decisions must be made that balance production and profits with environmental benefits. At the center of environmental considerations are living soil organisms. The question is, "Can we be productive in growing food in our gardens and on farms and also benefit soil life -- our 'undercover livestock'?

Where Have We Been?

Where Are We Going?

I'm your tour guide "Willy" Follow me!!

Living Soil Unit I featured the earthworm as the "Master Soil Builder" in:

1. understanding soil biology principles,
2. recognizing the relationship among plants, animals, and the soil;
3. discovering the impact of tillage and nutrient management on soil health;
4. discovering the role of earthworms in maintaining good soil health; and
5. exploring earthworm management

In reflecting on Unit I, participants learned the there are important principles to follow in designing tillage, nutrient management and pest control systems that will provide the proper shelter and food for earthworms and other soil life, which are an important key to life. The principles are as follows:

> **The proper combination of living soil organisms can be profitable as well as environmentally sound in increasing nutrients, reducing the need for chemical fertilizer, and improving the soil structure for plant growth.**

Tillage

1. Heavy tillage discourages earthworm activity. Disking or plowing in the fall or spring will destroy the earthworm tunnels, as well as other soil life.

2. Tillage, such as plowing and disking, destroys soil structure, as well as the pathways of soil life. This leads to soil compaction, soil crusting and sealing of surface pores, and increased water runoff and erosion.

3. No-till farming is emerging as the greatest agriculture advance of the century in terms of conservation, the environment and productivity. Leaving unharvested plant parts on the ground provides a surface cover that "provides a roof over their heads", and carbon to feed beneficial bacteria and fungi that recycle the organic matter into a form that plants can use.

4. In ridge-till farming, the seed is planted on the ridge and the tractor wheels are maintained in the valleys between rows. This tillage system provides a good source of food and shelter for soil life around the seed and emerging roots, and between the rows (valleys) where the residue is placed.

Pest & Nutrient Management

1. A good crop rotation of alternating grain and legume crops breaks up insect pest cycles, which reduces the need for chemical pesticides. Natural nitrogen is provided by the symbiotic relationship between the legumes and nitrogen fixing bacteria in the root nodules. Although grasses can be used in the rotation to break up the pest cycles, the teamwork between the roots and bacteria provides natural nitrogen in the soil for crops that follow legumes.

2. If chemical pest control is used, it is essential to select pesticides that are not harmful to soil life. Read and follow directions on the labels of pesticide containers and research the use of bioinsecticides to reduce harm to soil life.

3. Pesticides that are applied in a small band over the row or applied only on spots where needed can reduce costs, save energy, and reduce contact with soil life. This type of chemical application is often referred to as "banding" or "spot treatments."

4. Fertilizer applied next to the plant roots, not in excess of plant needs and at a time when the plant needs the nutrients, is cost effective and less apt to contaminate water.

5. Livestock manure applied to the soil and next to the crop row increases soil life activity, increases nutrients for the crop, and reduces the amount of chemical fertilizer needed for a healthy crop.

Unit II builds upon concepts included in Unit I with a practical application of biology principles in land and water management for both the city and farm (with special emphasis on soil microorganisms).

Unit II will take you on a tour of the "underworld" with "Willy" the worm as your guide. For some, the tour may be more like a trip to the underground zoo. The more you learn about your "underground" livestock, or zoo animals, the better decisions you can make in managing land and water, balancing production with the environment.

Balancing Human Activity with Soil Life

Directions: Place the two groups of words for "Human Activity" on index cards to be put in a box from which to draw. Place the three "Health of Soil Life" benefits on the chalkboard.

Human Activity

- Tillage management
- Pest and nutrient management

Think of us before you decide

Health of Soil Life

1. Protect home and burrows from physical abuse
2. Protect the animals and plants from being poisoned.
3. Feed the animals and plants for their energy and reproduction (not in excess of needs)

To Play the Game: Divide the participants into three teams. Two teams will compete against each other and the third team (or the instructor) will referee the activity. Place the two Human Activity cards in a box for drawing. Teams will alternate in drawing a card from the box and will respond to the topic drawn. The object of the game is to describe a practice (representing the topic drawn from the box) that will benefit the health of soil life. One point will be awarded for each of the three **Health of Soil Life** benefits.

Example: Team one draws the card labeled pest and nutrient management. The team members confer with each other to decide on a pest and nutrient management practice that would benefit soil life. For instance, they may say, **"Apply fertilizer in the spring after the plants have emerged from the ground rather than in the fall of the year."** The referee team would award one point to team one as their answer addresses Health of Soil Life benefit #3.

The most points to be awarded for any one answer would be three, if the answer included all three of the Health of Soil Life benefits. The referee team can decide on a time limit for each team's answers and the duration of the game.

The team winning the most points within the time limit will be declared **"Champion Soil Life Managers."**

Case Study 1

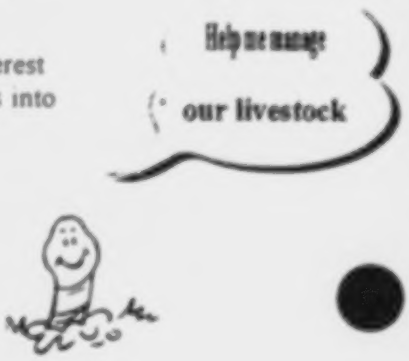
Land Management with "Undercover" Livestock

Decision Maker:

Manager of land
There are two types of people that could manage the land, and participants have two options

Option one: An individual who manages a farm
Option two: A city council that leases farmland which drains into a city water supply.

The class as a whole could decide on one option, depending on the interest of the participants. Another approach would be to split the participants into two groups and have each group take an option. This would allow participants to compare the types of decisions made depending on the interests of the managers.



Background:

The owner or renter of land that you manage reads the following article and asks you for your opinion on how to manage the land. In the past, the owner has used traditional tillage that buries crop residue and disturbs soil. The owner had used several different tillage operations, without regard to what effects they might have on soil life. Land managers must not only properly manage livestock on our farms to make best uses of resources, they also need to properly manage those animals that are under the ground (undercover livestock). The article reads as follows:

> *As many as 100 night crawlers per square yard burrow into farm fields left untilled. On these fields Agricultural Research Service (ARS) scientists found that two inches of water soaked into the soil in just 12 minutes, compared to two hours for tilled fields without worms. As a result of more water stored in the soil, less runs off the fields to carry away valuable topsoil and nutrients. Another plus for earthworm-filled fields: The worms' mucus-lined burrows provide plant roots with nitrogen-lined corridors to follow in the soil. Tillage destroys these burrows. Because plant material left after harvest provides food and keeps soil cool and moist, earthworms stay closer to the surface and are more active in no-till fields. (Information from the National Soil Tilth Laboratory, Ames, IA.)*

(Continued Case Study 1)

Decision:

Can a system to develop soil life for erosion control and water/nutrient management be used profitably on my land? (Groups are to study and report on their decision and reasons for their decision based on the following issues, alternatives and study questions.)

Issues:

*Management skills
*Proper equipment
*Cost of changing operations
*Risk of the new system
*Image portrayed to neighbors
*Savings associated with recycling of organic matter through increased soil organism activity.

Alternatives:

*Continue present traditional tillage system.
*Try a small area using a no-tillage system with an experienced person doing the tillage.
*Experiment with some small plots to determine value of changing to the new system.
*Sell present tillage equipment and buy the new equipment that will effectively work in the new system and plant the entire acreage using the new system.
*Other Alternatives

Essential Information:

*Equipment costs and availability of rental equipment.
*Skills needed to change to new system.
*Soil survey report.
*Research information on value of no till in erosion control and water/nutrient management.
*Availability of custom no-till machinery.

Study Questions:

1. Can I make a reasonable profit changing to a no-tillage system?
2. With the new system, can I reduce costs of purchased fertilizer?
3. What are the environmental benefits of a no-tillage system? (Erosion control, reduced chemical and nutrient runoff and soil development.)
4. What changes in soil life will occur if the new system is utilized?

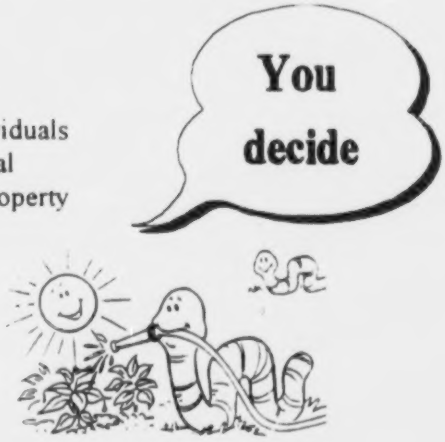
Case Study 2

Your Decision May Not Be Popular

Decision Makers:

City Environmental Commission

Background:



The city council owns 10 acres of land that it leases to individuals for gardening. No rules exist that regulate tillage or chemical management for the individual gardeners. Owners whose property lies below the garden area have made complaints. They claim that their properties are being damaged by erosion and runoff from this area. The city council has asked the **Environmental Commission** members to come up with recommendations to correct this problem. Commission members are split as to the best solution for the problem:

1. Half of the Environmental Commission members favor building a water/sediment basin below the garden area and letting the individual gardeners continue gardening as they have been.

2. The other half of the members want to develop leases with the individual gardeners to insure that:
    a. chemicals used will not harm earthworms and soil organisms, and
    b. the tilled garden areas must be mulched to reduce erosion, increase moisture conservation, and stimulate the activity of earthworms and other soil organisms.

Decision:
What are the potential arguments from each side regarding the decision that needs to be made? Why would one decision not be popular with those who prefer the other decision? Develop a recommendation to the city council to solve the soil erosion and water quality problem. (Groups are to study and report on their discussion and reasons for their decision based on the following issues and study questions, and come up with a recommendation to the city council.)

(Continued Case Study 2)

Issues:

*Cost of erosion control and water quality practices to the city and to the individual gardeners.
*Environmental benefits of the options.
*Benefits to the individual gardeners of each option.
*Kinds of tillage presently used by gardeners.
*Kinds of chemicals presently used by gardeners.
*Types of tillage, mulch, and chemicals best suited to the development of earthworms and their soil life.
*Value of earthworms and soil life in developing soil that will allow water to soak in more rapidly and provide natural nutrients to the plants.

Alternatives:

*Build a water/sediment basin to catch sediment and chemicals attached to sediment in water runoff.
*Develop rules in individual leases to solve the problem by requiring individual gardeners to use proper soil and chemical management
*A combination of the alternatives mentioned above.
*Prohibiting the use of the area for gardens.

Essential Information:

*Skills needed to design and develop a budget for the water/sediment basin.
*Labels on chemicals to determine which chemicals will adversely affect soil life.
*Availability of mulch for gardens.
*Skill in developing a lease to include soil and chemical management.
*Skill in tilling gardens to enhance development of soil life.

Study Questions:

1.Which system will best solve the problem for the downstream property owners and provide the most environmental benefits?
2.Which system would benefit the gardeners the most?
3.Which system will cost the city and gardeners the least?
4.Is mulch readily available for the gardeners?
5.Who will design and construct the water/sediment basin?
6.What will be the effect of either decision?

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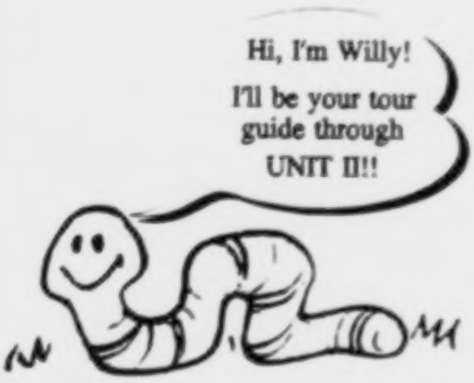
UNIT II - "Undercover Livestock"

Why Are Soil Organisms Important to Modern Agriculture?

A good soil environment is important for everyone, because soil is the medium that sustains life. Food for most living things comes from the soil, so a productive soil is essential. We as consumers expect quality in the foods we buy at the grocery store, but we don't always think of the processes that bring food to the store. Agriculture is so important for survival that everyone should learn where food really comes from. Modern agriculture makes use of many innovations to produce more food at a faster rate than in the past. This allows us to choose more products that we like. It also means that it is becoming more important than ever to take care of the natural resources from which we produce food.

Sustainable agriculture is the term applied to the practices involved in maintaining the resource from which all plants grow: the soil. The soil environment is precious, and care must be taken to preserve its productivity. For people involved in agriculture, this concept is not new. Nevertheless, farmers, gardeners, and others must be especially sensitive in order to maintain a good soil environment.


Hi, I'm Willy!
I'll be your tour guide through UNIT II!!

This sensitivity must begin with an awareness of a productive soil's natural components: the organisms that make soil alive. Attention must be focused on creating a favorable environment for these organisms, because they, in turn, create the balanced ecosystems necessary for the growth of usable resources, especially in agriculture. Soil microorganisms are an important link to all living things. If they die, eventually we humans also will die. In both agriculture and urban settings, crop fertility and weed/pest control are very large concerns. With rising costs and potential damage done by the misuse of fertilizers, herbicides, and pesticides, it is time to examine the soil's natural defense mechanisms. The heart of agriculture is profit, and if farmers are interested in enhancing their existing resources, one method can be found by learning to work in harmony with the soil organisms under their feet!!

What Is Contained In This Unit?

Unit II will focus on the living components of soil soil organisms. Soil organisms break down the plant and animal residues and wastes, as well as the inorganic materials, that provide plants with the nutrients they require for growth. Although this unit has an agricultural focus, it is strongly linked with science. It is important to include the science component so that participants will understand how soil organisms make the soil a living and productive resource.

This unit provides "hands-on" opportunities for participants to discover the heart of the food manufacturing plant -- soil organisms! Unit I focused on the earthworm, and Unit II will use the earthworm to guide you through the underground community. **Willy the Earthworm will be your tour guide throughout this unit.** In each section, participants will be introduced to different types of soil organisms. The following paragraphs give a brief look at what the unit is all about, and why it is so important.

What Is The Role Of Soil Organisms?

Soil organisms are the animals and plants that live almost entirely within the soil. There are two different types of organisms. *Macroorganisms* are visible to the naked eye and are mainly soil animals and the roots of plants. *Microorganisms* are tiny and can be seen only under a microscope. The number of microorganisms is mind-boggling! A gram of soil often contains one to four billion bacteria, 8,000 to one million fungi, and as high as 100,000 soil algae. An acre of soil contains between 200 and 1,000 pounds of earthworms.

Macroorganisms (for example, earthworms, springtails, and cockroaches) chew the plant residues into smaller pieces, making food for microorganisms. Other macroorganisms (spiders and centipedes) prey on these plant-feeding organisms; yet others (ants, beetles, and mites) feed on both decaying vegetation and other organisms that may be dead or alive. Another group (various larvae and nematodes) specialize in eating roots or sucking root juices.

Soil microorganisms play a vital role in the soil's organic cycle, because they decompose most plant and animal wastes. The nutrients that are released through decomposition are taken up by plant roots. Most are very small, often single-celled plants such as algae which can make sugars by photosynthesis. Fungi (including yeasts) are very effective at rotting damp fragments of wood, leaves, or roots. Bacteria can decompose most organic (and inorganic) compounds, and, in some cases, they even produce natural nitrogen fertilizers from the nitrogen in the atmosphere. Actinomycete bacteria produce the distinctive, earthy smell of soils.

Why Are Microorganisms Important In The Soil?

In an average topsoil, these microorganisms make up about five percent of soil organic matter. They are important because the nutrients they contain are released after their short lifetimes (one to two years). The remaining 95 percent of the soil organic matter is inactive humus. Humus is the end product of the transformations of plant residues, soil organisms and the microbes' waste products. Microorganisms and humus play an essential role in producing a rich, fertile soil that has good water-holding capabilities.

Characteristics of a soil microorganisms include:

1. Microorganisms in the soil rarely act alone.
2. Viruses are the smallest of soil organisms.
3. Bacteria are the most numerous microorganisms in the soil.
4. Actinomycetes are important in soil transformations and give the soil its smell.
5. Fungi help in the breakdown of cellulose and lignin, which are found in plant residues.

Microorganisms play a major role in soil fertility. Several microorganisms -- bacteria, for example -- transform nitrogen from one state to another. This transformation allows plants to use nitrogen that otherwise would be unavailable to them. Special bacteria also can transform other minerals, such as iron, manganese, and sulphur from unavailable (inorganic) to available compounds for plants by combining them with oxygen. Microorganisms are also important in the decay process of residues, because they release carbon dioxide into the air.

Like other living things, soil microorganisms need oxygen, moisture, and a source of food. To promote microbial growth for healthy, productive soil, the following soil conditions must be considered: structure, aeration, amount of organic matter, acidity, and proper handling of the soil. These considerations are essential for enhancing the environment in which microogranisms thrive.

Career Opportunities In Soil Science:
Much is known about outer space. Little is known about the inner space of our soil communities of living organisms essential to life on earth. There are research and educational opportunities to consider in helping to further explore the unknown inner space. This educational unit will provide participants with the background and concepts to help them prepare for careers in the following fields. **Which career interests you most?**

Ecology
Earth Science Teaching
Agriculture Teaching
Land Use Management
Soil Conservation & Soil Science

Research
Horticulture
Biology
Microbiology

Extension
Agronomy
Wildlife Conservation
Agribusiness

Unit II - a

Exploring The Underground Community

Soil Life: The Foundation of Soil Health and Food Production

Introduction

Many people perceive the soil as lifeless material. This is not so! Soil is teeming with life. **Below the surface of the land, there is another world to be discovered -- rich, variable in colors, textures, and smells, and pulsating with life.** Soil is the place where innumerable different types of plants and microorganisms live. Together, they play an active and indispensable role in Earth's life cycle. Most of these living organisms are so small that they are impossible to see without a microscope. But, there are large ones that can be seen without the help of a microscope. Seventy to eighty percent of the soil's metabolic activity is generated by microorganisms, such as bacteria, fungi, actinomycetes, and algae. The most important work performed by these microbes -- billions in every handful of soil -- is to convert nutrients into forms plants can use for growth, and to break down organic material into humus, which also aids in the soil's ability to hold water.

Objective

Through a good cross-section of "hands-on" participant activities and laboratory demonstrations, participants will be introduced to various types of soil life and the roles they play in soil fertility and sustainable agriculture.

Competencies

1. Identify and demonstrate growth of microorganisms.
2. Follow directions.
3. Utilize equipment correctly.
4. Demonstrate recycling of organic matter.
5. Write an essay and develop a poster.
6. Compare soil stability.

Come Tour My
Inter-Chambers

Materials

Can of soil
Teaspoon
Leopold Center flyer
Agriculture's Impact on the Living Soil videotape (13:40)
Refer to Lab activities

Information

INFO-MICRO-2 Outer vs. Inner Space
INFO-MICRO-3 Life in a Teaspoon of Soil
INFO-MICRO-4 Vocabulary Builder

INFO-MICRO-5	World's Largest Collection of Molds, Yeasts, and Bacteria

Activities

ACT-MICRO-1	Largest Recycling Plant on Earth
ACT-MICRO-2	What's in This Teaspoon?
ACT-MICRO-3	A Day in the Life of a Microbe
ACT-MICRO-4	Knowledge Builder
ACT-MICRO-5	Structure of the Topsoil (pre-activity)
ACT-MICRO-6	What Lives Between Your Toes ?
ACT-MICRO-7	Vocabulary Challenger

Laboratories

LAB-MICRO-1	Soil Building
LAB-MICRO-2	What Lives Between Your Toes?
LAB-MICRO-3	Residue Utilization

Visual Master

VM-MICRO-2	Tour of the Underworld
VM-MICRO-3	Earth's Recycling Factory
VM-MICRO-4	Willy's Team
VM-MICRO-5	"Quotable Quotes" - Albert Schweitzer
VM-MICRO-6	"Quotable Quotes" - Rachel Carson
VM-MICRO-7	Summary

Teaching Procedure

1. As **Part A** to an **Interest Approach,** ask the following question Where is the largest and most important fertilizer plant on earth located? Ask for discussion, but don't give participants the answer yet! It's time to trade the telescope for a microscope To illustrate this concept, show "Agriculture's Impact on Living Soil" videotape Following the video, use **ACT-MICRO-1** (Largest Recycling Plant on Earth) to ask for participant's perceptions using a "team" approach Answers to the discussion questions are as follows

Q1 What is your favorite sport?

A1 From their answers, pick out the team sports.

Q2 What is the importance of teamwork in these sports?

A2 The fact that the players must work together to accomplish their goal - of winning the game.

Q3 What is at the heart of the largest recycling plant on earth?

A3 Earthworms, macro and microorganisms.

Q4 How do the living soil organisms operate as a team?

A4 Each has its important part to play in recycling organic matter to nutrients that are made available to other animals and plants. They depend on each other like a running back and the offensive line on a football team, or a pitcher, catcher and batter on a baseball team.

Q5 If you destroyed one of the team members, like the microorganisms, what would the results be?

A5 The partially decomposed organic matter would not be broken down further to make important nutrients available to other animals and plants. This would affect the fertility of the soil by decreasing its productivity.

Q6 If you were to compare living soil organisms to a football or baseball team, in what position on the team would you place the earthworms? And why?

A6 Some might say the center and the quarterback, or pitcher and catcher, because the earthworm starts the recycling process and depends on others to carry it out, just as the center and quarterback, or pitcher and catcher, initiate the play and then look to other team members to help carry it out.

For **Part B** of the **Interest Approach**, use **INFO-MICRO-2** (Outer vs Inner Space) to make participants think about inner space compared to outer space and equate the importance of the two types of "spaces."

2 To introduce the concept of soil life, bringing a can of soil to class. Keeping the participants' attention focused on the soil, bring out a teaspoon, remove a spoonful of soil from the can, and ask them the questions provided on **ACT-MICRO-2** (What's in This Teaspoon?). Provide participants with **INFO-MICRO-3** (Life in a Teaspoon of Soil). Have them read the information and continue answering questions on the **ACT-MICRO-2** (What's in This Teaspoon?) worksheet.

Q1 What is in this small amount of soil?

A1 Get participants to think about the life in the soil -- microorganisms and insects.

Q2 Why do you think microorganisms and insects are important?

A2 To help the soil stay productive.

Q3 How do the microorganisms and insects interact?

A3 They help one another by breaking down different residues, similar to a factory assembly line with each microorganism doing its special processing. Organisms at each stage of the process help residues become a rich soil, and make nutrients available for other living things.

Q4 If one microorganism or insect is missing, will the process of decomposition be able to continue?

A4 The process will take a lot longer and may not be effective if one kind is missing.

Q5 What effect do our activities have on the soil?

A5 We alter that natural process by changing the microorganism's environment.

Answers to questions relating to Life in a Teaspoon of Soil.

Q6 How many organisms are found in a teaspoon of soil?

A6 10 billion bacteria, one million fungi, 100,000 algae, 10 million actinomycetes, 10,000 protozoa.

Q7 Can these organisms function on their own?

A7 No, they are dependent upon one another, because some organisms break down residues that other organisms feed upon.

Q8 Where in the soil does most of the activity take place? Why?

A8 The top layer of soil. This is where organisms are exposed to sun, rain and air.

Q9 What do some of these organisms do?

A9 Antibiotic production, convert organic matter into forms used by other microorganisms and plants, nitrogen production, trap light energy, form acids.

Q10 What is the effect of microorganism activity in the soil?

A10 The soil is loose and crumbly, which lets water and air penetrate. This helps plant roots to take hold.

Q11 What is the relationship of humans to microorganisms?

A11 They are related in the cycle of life, in which microorganisms help plants grow, and plants are used by humans for food.

Q12 What are some of the various shapes of bacteria? How do they increase in number?

A12 Shapes are round, spiral, and rod; they increase by dividing or splitting in two.

Q13 What do fungi look like? What is their function?

A13 Fungi are white, threadlike organisms that are linked together by hyphae. They break down organic matter into usable forms for plants, but they are also important "weavers" of the soil, holding soil particles together.

Have participants read and prepare an essay on their thoughts to share with the class.

3. Hand out the Leopold Center flyer "The Far Side" to introduce Willy the earthworm as our tour guide through the "underground world." Review the flyer to illustrate why we chose to feature the earthworm as our tour guide.

4. Use **VM-MICRO-2** (Tour of the Underworld) to illustrate **ACT-MICRO-3** (A Day in the Life of a Microbe) to help participants understand what the inner space is like. The view master was developed in a cartoon format so that it is more interesting to the participants. It is a maze that organisms travel in the soil spaces to reach plant roots, and shows various types of soil life.

   Divide the participants into groups and ask them to either role-play, act out or draw pictures on the chalkboard to illustrate one concept from this activity.

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5 Soil structure is affected by the activities of soil organisms. The previous activities introduced participants to the idea of inner space and the activity that takes place within that space. The next activities will analyze topsoil and will seek participant's perceptions of soil structure. Provide participants with **ACT-MICRO-4** (Knowledge Builder) to identify the different types of soil structure.

Q1 Match the following terms with their correct definitions.

g	Structure	a	Prismatic/columnar
f	Bacteria	d	Microbes
c	Aggregate	l	Tilth
k	Actinomycetes	h	Fungi
i	Structureless	j	Platy
m	Soil Ecosystem	b	Residue
e	Blocky/nutlike/granular		

Q2 Identify and explain which of the above terms are beneficially affected by soil life.

A2 Soil structure, aggregate, and tilth are beneficially affected by soil life through their physical activity, line burrowing, and the by-products they produce that binds soil particles together.

6 To investigate participants' perceptions relating to soil structure, use **ACT-MICRO-5** (Structure of Topsoil) as a "pre-activity," and keep them to compare with a similar activity at the end of Unit II. Perceptions of participants should change between the pre-activity and post-activity if they have learned the important concepts.

Q1 Describe the role that soil organisms play in the development of a dark-colored, granular-structured soil.

A1 Soil organisms recycle the crop residues and mix them into the soil, giving it a dark color. The mixing action of the organisms helps to make the desirable granular structure.

Q2 Describe what occurs to soil structure, color, and organisms when soil is plowed continuously with little or no organic matter added to the soil.

A2 The soil essentially becomes structureless, with no aggregates to hold the plant roots in place. Water soaks right through it and does not stay to nourish the plant roots. Few organisms would exist, because the upper layer of the soil, which is their habitat, has been disrupted.

7 Hand out **LAB-MICRO-1** (Soil Building) and ask participants to carry out the laboratory activity. This will allow them to see the importance of soil tilth and see the differences in aggregates and soil stability with various kinds of organic matter.

Test #1
The percentage of water-stable aggregates will change, depending on the type of residue used. Different residues will form different aggregates, and some will be better than others. The stable aggregates are the ones that will not come apart when dipped into the water.

Test #2
The kinds of residue will affect the structural stability of each soil sample. Differing volumes of water should be needed to test each sample.

Test #3
Some of the samples will be stickier than others, depending on how the soil is structured.

8. Once participants know the processes related to soil structure, they will begin to understand the role microorganisms play in changing soil structure in recycling crop residues. Use **VM-MICRO-3** (Earth's Recycling Factory) to introduce participants to various soil microorganisms.

9. Utilize **VM-MICRO-4** (Willy's Team) to illustrate the classification breakdown of each type of organism. Emphasize the fact that upcoming units will deal with some of these organisms in depth.

10. To introduce the concept of bacteria, use **ACT-MICRO-6** (What Lives Between Your Toes?) This activity will ask participants about their perceptions and what they think they will learn. Continue with **LAB-MICRO-2** (What Lives Between Your Toes?) This lab will show that bacteria can be found anywhere, and will outline what conditions are favorable for bacterial growth.

11. Participants can become more aware of the importance of nature, soil, and living soil organisms through discussion quotes written by Albert Schweitzer and Rachel Carson. Use **VM-MICRO-5** ("Quotable Quotes," Albert Schweitzer) and **VM-MICRO-6** ("Quotable Quotes," Rachel Carson), and lead a discussion based on the following discussion questions:

VM-MICRO-5 ("Quotable Quote" - Albert Schweitzer)

Q1 Why should we consider ourselves united with the life in nature?

A2 We are all involved in the cycle of life. Nature helps us to survive by giving us soil to grow food, and in return we have to take care of nature to help other organisms survive that help support us.

Q2 Can we live life for ourselves only?

A2 No. If we considered our needs only, those needs would not be met because there would be no resources from which to draw.

VM-MICRO-6 ("Quotable Quote" - Rachel Carson)

Q1 What does this quote mean to you? What do you think?

A1 Responses will vary

Q2 How does our life depend on the soil?

A2 It provides the resource from which we can grow food to live

Q3 How does soil life depend on us?

A3 We can provide a favorable environment for organisms to live. We can avoid disturbing their habitat through sustainable agriculture and promote the growth of organisms

Q4 How did inert materials become soil? What helped the process?

A4 Lichens broke down the inorganic rocks, and then mosses took over, which promoted other life forms to join in the decomposition process

12 Use **LAB-MICRO-3** (Residue Utilization) to show how soil organisms -- in this case -- earthworms -- recycle residue. This lab will show participants that earthworms will seek out the residue and use it, thus changing the amount that is on the top. This will change soil structure and its ability to hold water

13 Use **INFO-MICRO-** (Vocabulary Builder) to review key terms in the unit

14 Hand out and have participants read **INFO-MICRO-5** (World's Largest Collection of Molds, Yeasts, and Bacteria). Ask for their reaction. **What value does this have to society?**

15 Provide participants with **ACT-MICRO-7** (Vocabulary Challenger) to review key terms for the unit

Across: 2. bacteria 5. biological 6. microorganisms 7. ecosystem
9. protozoa 10. fungi 11. teaspoon

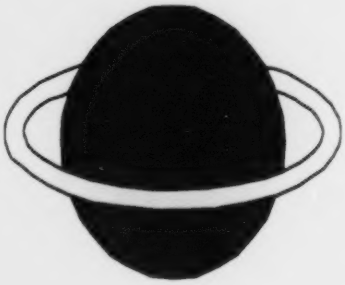
Down: 1. ARS 3. actinomycete 4. nitrogen 8. erosion

16 Use **VM-MICRO-7** (Summary) to summarize Unit II-a

Oregon State University has a Soil Microbial Biomass Service, where you can find out what living soil organisms are in any given soil sample. Cost ranges from $5 for active bacteria count to $95 for all seven tests, including the number and community structure of protozoa and nematodes. Contact Elaine Ingham, Botany and Plant Pathology, Oregon State University, Corvallis, OR 07331-2902, phone (503) 737-7715

Outer vs Inner Space

When the Apollo astronauts landed on the Moon, the world's attention focused not only on the discovery of a desolate lunar landscape, but on our spectacularly beautiful planet Earth of blue-green oceans, brownish land masses, white polar ice caps and patterns of clouds swirling around earth. Our interest in our environment seemed to peak during this historic mission. Outer space did not seem so far away and unknown.



While our attention was on the moon and the visible precious resources on Planet Earth, relatively few people realized the existence of another universe below their feet. **Below the surface of the land there is another world to be discovered - rich; variable in colors, textures, smells and pulsating life!** This "underground world", so vital to our existence, is our complex community of living soil organisms. The soil can tell us so much about our present-day environment and geologic history. **It is the home of millions of living things -- a recycling factory for so much of the energy that sustains life.** The absence of our world of living soil organisms was not so obvious to the Apollo astronauts when they compared the lunar surface to Planet Earth, because it is difficult to comprehend the true value of our living soil. **Even though we come into contact with the soil's vast and varied inner space every day, there is little known about it - probably less than what is known about outer space!**

EARTHWORM
CYCLE OF ORGANIC RESIDUE

Life in a Teaspoon of Soil

by Shirley Foster Fields

Let's take an imaginary journey to another world-- a world we cannot see, but that exists, nonetheless, wherever there is fertile soil. Enter this world and you will observe countless living creatures that are essential to the soil's productivity and to your own survival and health. In fact, life in this invisible realm is so rich and varied that it is almost beyond belief. **Begin by pretending that you are no longer human--each of you is a single celled amoeba, tinier than the tip of a needle and visible only through a microscope. You are no longer in the classroom, for you have fallen into a teaspoon of rich topsoil.**

The first thing you notice in this new world is the billions of busy microorganisms that inhabit it. ***To your amazement, you discover that in this single teaspoon of soil there are about 10 billion bacteria, one million fungi, 100,000 algae, 10 million actinomycetes, and 10,000 protozoa.*** In only one cubic inch of fertile soil, there are more individual living organisms than there are people on earth. Look around you: The population is greater and the tireless work force is busier than all the people in the combined cities of Tokyo, London, Paris, Calcutta, and New York!

What does all this mean? Why the ceaseless activity? What is happening here?

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All of these living organisms are in a whirl of interrelated activity. Day and night, these tiny individuals work together to build, enrich, and restructure the soil. The work force is busiest and the populations of organisms are greatest in the top layer of the soil. For it is here that the sun, air, and rain assist microorganisms in their ceaseless tasks.

Soil microbiologists describe the unique characteristics and activities of each type of microorganism in lengthy and fascinating detail. Some organisms specialize in producing antibiotics. Many convert dead organic matter into soluble food materials for plants and for other microorganisms. Nitrogen, an indispensable constituent of all living tissues, exists in abundance in the air. **But plants would starve without the billions of nitrogen-fixing bacteria that exist in the soil.** It is the special task of these bacteria to capture the nitrogen and then convert it into molecules that plants can absorb.

Other microorganisms are able to trap the energy of light. Still others form acids that help dissolve minerals and rocks, releasing calcium, magnesium, potassium, and other nutrients that are absorbed by plants and are essential to human health.

What is the combined impact of microorganisms upon the landscape?

Their constant action not only enriches the soil with nutrients that are necessary to sustain human life--their work also keeps the soil loose and crumbly, allowing water and air to penetrate and plants to root and grow. Plants, in turn, develop intricate root systems that help hold the soil in place, thereby reducing erosion. When plants die, their decomposing roots become another food source for the microorganisms--a beautiful example of the interdependence of nature, and the creative cycle of life, death, and the renewal of life that flourishes in the natural world.

Obviously, we humans are involved in this cycle of life. For without the work of microorganisms, there would be no plants on Earth. Without plants, we, in turn, would lack the food we need for life. Clearly, there is a realm of nearly unimaginable power in the soil beneath our feet.

Before we leave this microcosmic world, let's observe the size of our companions there -- bacteria and fungi. How small is "small" and how big is "big" in this miniature universe?

Ask a microbiologist how small is "small" and how big is "big" in our invisible and visible worlds, and with mathematical precision, the biologist will tell you that a bacterium (singular for bacteria) compared with an earthworm is the equivalent of a small frog sitting beside a six thousand foot mountain!

The bacterium is infinitesimal and the earthworm is gigantic. Yet, they work day and night from season to season in rhythmic harmony, performing closely related and indispensable tasks.

Bacteria, we see, come in various shapes. Some are round; others are spiral or rod shaped. A small colony of these single -celled organisms -- about a dozen or so -- are perched on a particle of soil near the root of a soybean plant. **At this moment, their numbers are rapidly increasing.** They are busy reproducing themselves. But this is no conventional mating game. Bacteria do not unite with one another. Individuals simply divide -- splitting themselves in two. Considering the ease with which they reproduce, it isn't surprising that with a population of about ten billion in a single teaspoon of soil, they hugely outnumber all other microorganisms in the soil.

Now, more than three thousand million years since their birth, their ceaseless work continues. We know that some bacteria are harmful, causing diseases in man, animals and plants. Many others, though, are not only helpful, but indispensable to the cycle of life.

The dozen we see are among the indispensables! By splitting themselves in two, they have increased their numbers to two dozen now, and they are hard at work breaking down dead organisms into the simple molecules that the soybean can absorb for growth.

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We leave the soybean root now, and enter a fragrant forest. Here, quite another drama is unfolding. An inch or so beneath the forest floor, fungi are feasting on damp leaves and a fragment of rotting wood.

In this neighborhood of "plain Jane" bacteria, the appearance of the fungi is positively exotic. They are white, thread-like organisms, larger than bacteria, and linked together in long, trailing filaments called hyphae (pronounced "highfee"). We marvel at the beauty of these delicate filaments. They are like strings of dainty flowers, and we see that they perform two important tasks. Like bacteria, they break down organic matter into a form usable by plants. But they also help stabilize the soil. They are among the Earth's great "weavers". Their trillions of filaments hold soil particles together, strengthening the particles resistance to rain and wind that otherwise might cause the soil to wash or blow away.

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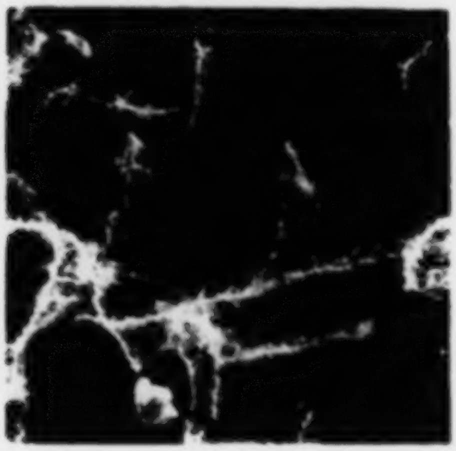
It is time for us to leave this hidden world beneath our feet and return to the classroom now. You are no longer an amoeba. You are you, fully human, and you have a moment to reflect upon your day in the soil.

As a traveling amoeba, what have you seen in a day? Your voyage has taken you to a universe within a universe. But you have glimpsed only a tiny portion of that amazing world. Inner space is a place of astounding complexity and magnitude, a place as vast and varied as outer space and our solar system. Like the solar system, the microcosmic world is a region that scientists are exploring still.

Shown below: a magnification of 25,000 times, shows the intricate network of fungi that binds soil particles. (Photo taken by Hari Eswaran through a scanning electron microscope, accompanied Shirley Foster Fields article in the *Science Scope Magazine*.)



Written by Shirley Foster Fields, adapted from Science Scope Magazine, February, 1993

VOCABULARY BUILDER

Unit II-a

Actinomycetes - A group of microorganisms, intermediate between bacteria and fungi that are active in decomposing and responsible for the earthy smell of soil

Aggregate - Lumps of various sizes formed by soil particles sticking together

ARS - Agricultural Research Service

Bacteria - Most numerous, extremely small, single cell organisms. Some bacteria provide a mucus that binds soil particles together.

Fungi - A group of larger organisms that lack chlorophyll and may be linked together in long filaments called hyphae that help decompose organic matter.

Macrofauna - the largest animal related soil organisms -- includes burrowing animals such as the mole and pocket gopher.

Mesofauna - middle sized animal related soil organisms -- includes earthworms and soil insects such as arthropods, ants, termites, beetles, et.

Microbes (microorganisms) - Living creatures so small they can only be seen through a microscope (bacteria, fungi, actinomycetes).

Microfauna - the smallest animal related soil organisms -- microscopic organisms such as nematodes, bacteria and fungi.

Midden - The castings of earthworms which serve as a lid to their burrows.

Residue - The plant material left on the soil surface after a crop has been harvested.

Rotifer - A microscopic organism whose mouth looks like two rapidly revolving wheels.

Soil Ecosystem - A system in which plants and animals inhabit the same location.

Soil Organisms - Living creatures -- earthworms, microorganisms, and insects -- that live in the soil.

Soil Structure - The grouping or arrangement of soil particles

Soil Tilth - The "fitness" of a soil for cultivation. How a soil's physical properties affect it's capacity to support plant growth.

World's Largest Collection of Molds, Yeasts, and Bacteria

Some of science's most valuable tools are tucked away in a dark room on the third floor of the National Center for Agricultural Utilization Research (NCAUR) at Peoria, Illinois One of the world's largest microbial culture collections, the ARS culture collection contains more that 80,000 specimens of yeasts, molds and bacteria of agricultural and industrial importance Specific cultures related to microbiological inventions are deposited in conjunction with U S patent application into the ARS Patent Culture Collection. Since its establishment, the ARS culture collection has played a major role in the research on penicillin and other antibiotics, as well as on riboflavin, organic acids, xanthin and dextran gums, mycotoxin, and food fermentations.

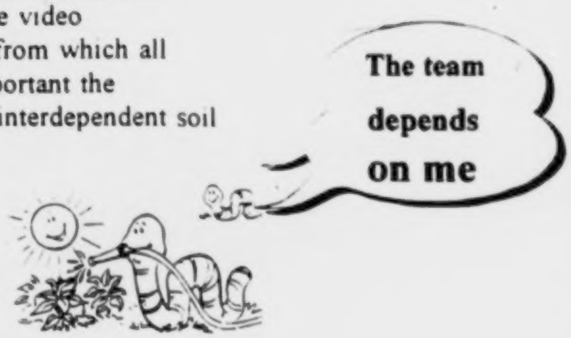
Although the culture collection formally began when the Northern Regional Research Laboratory (now NCAUR) opened in 1940, Cletus Kurtzman, head of the collection, says that its origin can be traced back to 1904. That's when Charles Thom joined USDA and began investigating Roquefort and Camembert cheeses. Thom and his assistant Margaret B. Church eventually acquired hundreds of mold cultures that became known as the Thom and Church collection. The collection was deposited at the USDA facility at Peoria when Kenneth B. Raper, a colleague of Thom's, became head of the culture collection. Additional molds and bacteria were also deposited in the collection when it was formally established.

"Other cultures have been added to the collection as they've been acquired by scientists in the USDA and the private sector.," says Kurtzman. "In some cases, entire collections that might otherwise have been lost to science because of retirements or changes in research programs have been accessioned." Most of the specimens in the collection are freeze-dried and stored in glass ampules. Specimens are stored at about 40°F and can be revived even after half a century. Some, though, are damaged by freeze drying and are instead frozen in liquid nitrogen to keep them alive. In the last decade, efforts have concentrated on finding microorganisms to use in the conversion of biomass to ethanol. Current and future work will be closely aligned with biotechnology. "Scientists are using microorganisms from the collection in research to find natural ways to combat weeds, insects, and fungal infections, " says Kurtzman. "We're also looking for ways to use microorganisms for the production of specialized organic compounds from low-cost agricultural products." Cultures from the general collection are provided free of charge to anyone involved with research and development. More than 4,000 specimens are requested annually, says Kurtzman. Culture strains deposited in the ARS Patent Culture Collection are maintained for at least the 17-year life of a U.S. patent and for 30 or more years when deposited under an international agreement such as the Budapest Treaty. The depositor may make the microorganism freely available on deposit or opt to wait until the patent has been issued.

Source Kurtzman, Cletus P "Worlds Largest Collection of Molds Yeasts and Bacteria" Agricultural Research USDA - Agricultural Research Service June 1992

Largest Recycling Plant On Earth

Have participants view the **"Agriculture's Impact on the Living Soil"** videotape to review the aspects learned in Unit I. The video concentrates on the soil as the nation's resource base from which all food is produced. It then moves on to show how important the earthworm is to soil quality. It describes the diverse interdependent soil community, in which soil organisms are dependent on each other. The process of recycling the organic matter into nutrients the earthworm at an early stage of recycling, and is then continued by microorganisms. The soil is considered to be the "largest recycling plant on earth". Just as the earthworm starts the recycling process as described in Unit I, Willy the earthworm will be your guide through Unit II. The earthworm is the "master builder" and in the underground community the microorganisms are the "team members". The linkages made in this team effort are so important that if there is a team member missing, the team will not be as effective.


The team depends on me

After showing the videotape, ask participants to discuss their perceptions of the team approach in the "largest recycling plant of earth" by asking the following questions.

1. What is your favorite sport?

2. What is the importance of teamwork in these sports?

3. What is at the heart of the largest recycling plant on earth?

4. How do the living soil organisms operate as a team?

5. If you destroyed one of the team members, like the microorganisms, what would the results be?

6. If you were to compare living soil organisms to a football team, to what position on the team would you place the earthworms? And why?

What's in This Teaspoon?

Answer the following questions:

1 What is in this small amount of soil?

2 Why do you think microorganisms and insects are important?

3 How do the microorganisms and insects interact?

4 If one microorganism or insect is missing, will the process of decomposition be able to continue?

5 What effect do our activities have on the soil?

Questions relating to **"Life in a Teaspoon of Soil"**.

6 How many organisms are found in a teaspoon of soil?

7 Can these organisms function on their own?

8 Where in the soil does most of the activity take place? Why?

9 What do some of these organisms do?

10 What is the effect of microorganism activity in the soil?

11 What is the relationship of humans to microorganisms?

12 What are some of the various shapes of bacteria? How do they increase in number?

13 What do fungi look like? What is their function?

Now that you have read "Life in a Teaspoon of Soil" and discovered how soil organisms live, prepare an essay on your thoughts to share with the class.

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A Day in the Life of A Microbe

Shrinking to the size of a nematode - thinner than a piece of human hair - we slither down one of the many openings in the soil surface. We slip and fall helplessly through a cavernous chamber, the land in a shallow pool of water. A sluggish river of soil water soon sweeps us away as it winds in and out of a maze of hidden passages.

The air is cool and very moist. As our eyes adjust to the blackness, we realize we are not alone. Several bewhiskered rotifers - each spinning its propeller-like cilia - dart about chasing schools of bacteria. A tangle of rope-like fungal hyphae hangs from the ceiling of one chamber. In another, the hyphae are being grazed by a pair of mites - giant, hard-bodied, spider-like creatures. As we pass, another mite leaps upon one of them, grabbing it with claws and piercing its belly with its jaws. The second mite continues grazing, seemingly undisturbed.

Everywhere rubbery brown and black strands, like stretched sinews, bind the mixture of pebbles, rocks and boulders through which we float. At one point, we glimpse a ray of sunlight and feel fresh air wafting down a smooth, round shaft excavated by an earthworm. We feel the earth heave slightly as the worm continues to eat its way through the soil below, opening new passages and invigorating the earth with secretions from its gut.

Suddenly we see the destination of our subterranean stream. A snowy white root, like a huge translucent log, nearly blocks the passage ahead. It pushes toward us almost as fast as we are floating toward it. Our stream seems to disappear as the root absorbs it.

The air is pungent with aromas from the root. The water takes on a slightly brownish color as the exotic smells and tastes of root secretions overwhelm our senses. Our stream becomes ever more jelly-like as we near the root surface.

We are in the rhizosphere, the zone of peak biological activity around the root. The schools of bacteria have greatly multiplied. We see the root surface is nearly covered with clinging bacteria. In about a dozen spots a branched network of fungal strands emerges from the root to penetrate deep in the crevices in the walls surrounding the passage.

In places the fungi form dense thickets. These fungal and bacterial colonies give birth to so many rubbery fibers that they fill many of the smaller passages. A nematode about our size thrashes wildly in a fungal noose that trapped it before it could attack the root.

If this is what a microbe experiences in a single day - think about what it experiences in its life!

Be A Microbe For A Day

Choose one of the microorganisms discussed in "Life in a Teaspoon of Soil". In an essay of about one page in length, write a fairly detailed summary of that microbe's daily routine. Be creative -- pretend you are the microscopic creature!! You can illustrate this essay by using posters that show exactly where the microorganisms are located in the soil and how they move.

Weil, Ray R. "Inside the Heart of Sustainable Farming". The New Farm. January 1992.

Knowledge Builder
Unit II - a

1 Match the following terms with their correct definitions

___ Structure
___ Bacteria
___ Aggregate
___ Actinomycetes
___ Structureless
___ Soil Ecosystem
___ Blocky/nutlike/granular
___ Prismatic/columnar
___ Microbes
___ Tilth
___ Fungi
___ Platy
___ Residue

(a) A type of soil structure that has vertical cracks.
(b) The plant material left on the soil surface after a crop has been harvested.
(c) A cluster or clod of soil particles
(d) Living creatures so small they can only be seen through a microscope (bacteria, fungi, actinomycetes).
(e) A type of soil structure that has horizontal and vertical cracks.
(f) Most numerous, extremely small, single cell organisms. Some provide a mucus that binds soil particles together.
(g) A grouping or arrangement of soil particles.
(h) A group of larger organisms that lack chlorophyll and may be linked together in long filaments called hyphae that help decompose organic matter.
(i) Soil that does not cling together, or is a single mass.
(j) A soil structure that has horizontal cracks.
(k) A group of microorganisms, intermediate between bacteria and fungi that are active in decomposing and responsible for the earthy smell of soil.
(l) The "fitness" of soil for cultivation.
(m) A system in which plants and animals inhabit the same location.

2. Identify and explain which of the above terms are beneficially affected by soil life.

Structure of Topsoil

Plant and animal life greatly influence the processes of soil formation. The "structure" of a soil is defined as "the arrangement of it's parts" (the way the particles of soil are put together) Soil loses its structure after being plowed continuously and without the addition of organic matter It has a tendency to run together when wet with water We speak of good tilth, meaning the ease with which land responds to cultivation Soil organisms recycle plant and animal residues into soil organic matter The activities and by-products of soil life improve and develop the color and physical structure of topsoil The work of microbes keeps the soil loose and crumbly, allowing water and air to penetrate to become available for plant roots

Single grain structure is a soil condition in which grains of soil have independent existence The grains are loose, not held together *This is an undesirable condition* **Granular structure** is a condition where the soil particles are held together in small lumps which resemble bread crumbs in shape and porosity *This is a desirable condition* A dark topsoil indicates that living matter has grown and perished on the land and has been returned to the soil in the form of organic matter

1 Describe the role that soil organisms play in the development of a dark colored granular structured soil

2 Describe what occurs to soil structure, color and organisms when soil is plowed continuously with little or no organic matter added to the soil

3 Draw two pictures Imagine looking at the following with a powerful microscope Be creative!!

a) A magnified version of soil particles and organisms in single grained structured soils with little organic matter

b) Another version in a granular structured soil with lots of organic matter

Prepared by Eldon Weber, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa March 1994

What Lives Between Your Toes? Understanding Microbe Growing

Objectives

1. To familiarize participants with the idea that bacteria are beneficial to us in our soils
2. To make participants realize that bacteria found in places above ground, such as on their feet, are the same types of organisms found living in our soil
3. By reading their responses, to get a feel of the participants' understanding of these concepts

Read the following case and then answer the question below:

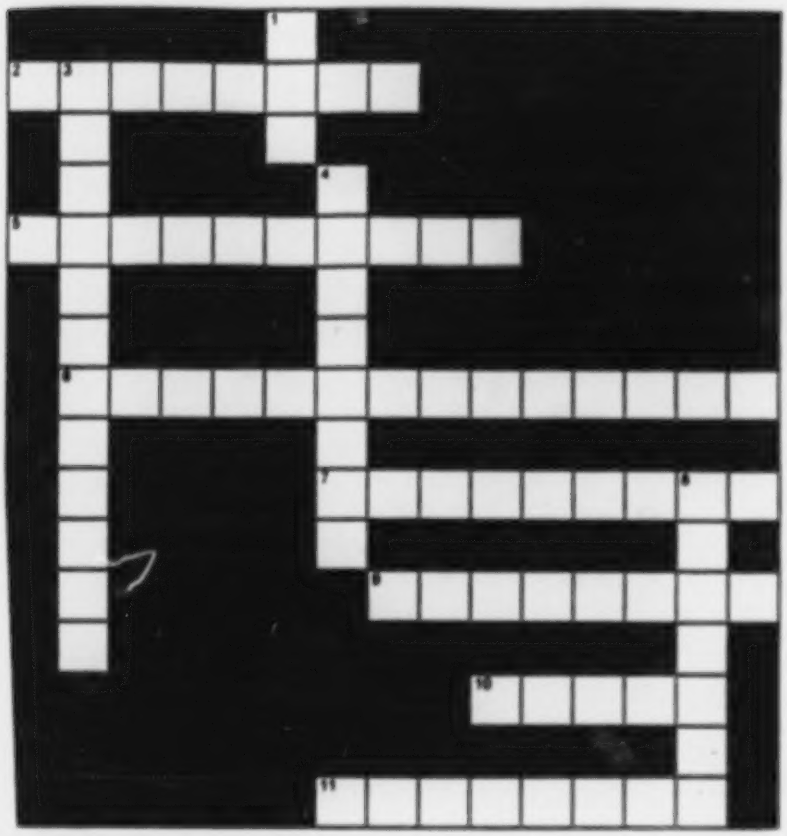
When you think of bacteria, what comes to your mind? For most people bacteria means disease, sickness, and GERMS. The average person has this normal idea that bacteria are little critters that do far more harm than good. The benefits bacteria provide for us aren't always understood. In food production, these microorganisms are very helpful in many ways. They help process our soils and make them rich so that the soil can grow crops. Even most professionals in the field of agriculture aren't very knowledgeable about the subject of soil bacteria.

Understanding the benefits of microorganisms such as bacteria (which are often called "soil microbes") is an important step in learning what happens in our soil. We know that bacteria can be the host for viruses that give us colds, and that these germs are present above the surface of the earth, but do we ever think of these tiny creatures living in our soil? They do many things for the soil. In the following activity, you will be able to collect some bacteria from your own feet. You will become acquainted with the growth of these microbes. It is important that you understand that these organisms also live beneath our feet as well as on our feet. They inhabit our soils!

In a few sentences, describe what you think you may learn in the following activity:

Source: Jok Church, "You Can With Beakman", 1991, Universal Press Syndicate 9/29/91. Printed in Des Moines Sunday Register.
Edited by Dr. Gaylan G. Scofield

Vocabulary Challenger - Unit II - a



ACROSS

2. The most numerous single celled organisms found in the soil.
5. The type of microscope used to view larger microorganisms.
6. Living creatures so small that they can only be seen through a microscope.
7. A system where both plants and animals can only be seen through a microscope.
9. 4 to 5 million of these organisms are found in a teaspoon of soil.
10. A group of single celled plants that lack chlorophyll.
11. Six million earthworms can be found in a _____ of soil.

DOWN

1. Abbreviation for Agricultural Research Service.
3. Microorganism active in decomposing and giving the soil it's smell.
4. An element that comes from the atmosphere and is found in all living tissues.
8. Microbes make the soil beneficial for plant roots, which hold the soil in place, decreasing _____

Prepared by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. March 1994

Soil Building

Introduction

Excessive tillage, erosion and reduced organic matter in the soil weaken the structure of soils. As the structure weakens, the soil tilth becomes poorer, crusting increases and soil permeability decreases. Soil tilth refers to how easily the soil can be tilled and the quality of medium for plant root development and growth. When tilth is poor, more power is required to till the soil.

Objective

Participants will be able to perform different tests on soil to determine soil quality.

Competencies

1. Follow directions to conduct an experiment.
2. Calculate the percentage of water-stable aggregates in the soil.
3. Determine the structural stability of soil.

Materials

1. Soil from several locations
2. Crop residue (3 or 4 kinds)
3. Scale
4. Petri dishes
5. Sieve with 0.25-mm openings
6. Buret with stand and beaker

Our team benefits soil quality

Procedure

1. Weigh 500 grams of soil.
2. Mix in 5% shredded residue.
3. Saturate the sample to field capacity.
4. Place in petri dishes and air dry or microwave.
5. Complete the above steps with different soil types and residues.
6. Prepare sample of each soil without residue.

Test #1

7. The percentage of water-stable aggregates in a soil can be determined by placing a weighed sample on a sieve with 0.25-mm openings. The sieve is then dipped repeatedly (fifty times, or some other standard number) in a container of water. The material remaining in the sieve is then dried and weighed. Calculate the percentage of water-stable aggregates.

Test #2

8 The structural stability of soil clods can be compared by letting water drip onto them from a buret. The volume of water required to wash the soil through the sieve into beaker is an indication of structural stability.

Test #3

9 Compare the amount of force needed to break apart the samples.

Conclusions:

1. In making comparisons on soil stability, which soils have the best soil tilth and why?

2. Explain what human activities lead to the development of the soil with the best and poorest soil aggregates?

What Lives Between Your Toes? Understanding Microbe Growing

Introduction

Bacteria is always present, and if left in favorable conditions, it will grow. We don't always know which environmental conditions promote the growth of bacteria and other microbes.

Objective

Participants will discover the bacteria that lives between their toes and the conditions that promote its growth.

Competencies

1. Identify environmental factors that favor bacterial growth.
2. Describe the growth of bacteria.

Materials

1. Clean mayonnaise jar or other suitable container
2. Unflavored gelatin - 1 box
3. Cotton swab
4. Clean water

Procedure

1. Boil 1/2 cup water.
2. Sprinkle in four envelopes of unflavored gelatin and let the gelatin dissolve.
3. Pour the gelatin mixture into the mayonnaise jar and set the jar on its side. Let the extra pour out.
4. Put on sneakers without socks and go exercise.
5. After the gelatin becomes hard (about 3 hours), take a cotton swab and rub it well in between all of your toes. Carefully brush the gelatin with the cotton swab in long strokes.
6. Close the jar and put in a warm, dark spot.
7. Observe after four to seven days.
8. Don't keep the jar any longer and **don't touch it inside**. Fill it with hot water, let it soak, empty it, then recycle the jar.
9. **Wash your hands!!**

Conclusions: In a few sentences tell what you learned from this activity. What was similar to your expectations? What was different?

Source: Jok Church "You Can With Beakman" 1991. Universal Press Syndicate 9/29/91. Printed in Des Moines Sunday Register
Adapted by Dr. Gaylan G. Scofield

Residue Utilization

Introduction

Simply leaving crop residues in the soil is an easy way to provide organic matter. Only a little organic matter is found in most mineral soils, but its effect on the soil is great. Organic matter is that portion of the soil that includes animal and plant remains at various stages of decay. Earthworms help improve soils by utilizing crop residues as food and breaking them down.

Objective

Participants will be able to observe how earthworms change the soil.

Competencies

1. Explain the differences in the soil due to earthworm activity.
2. Describe differences in the residue left on the soil.

Materials

1. Container 12" x 12" x 8"
2. Soil
3. Residue (3 different kinds)
4. Earthworms

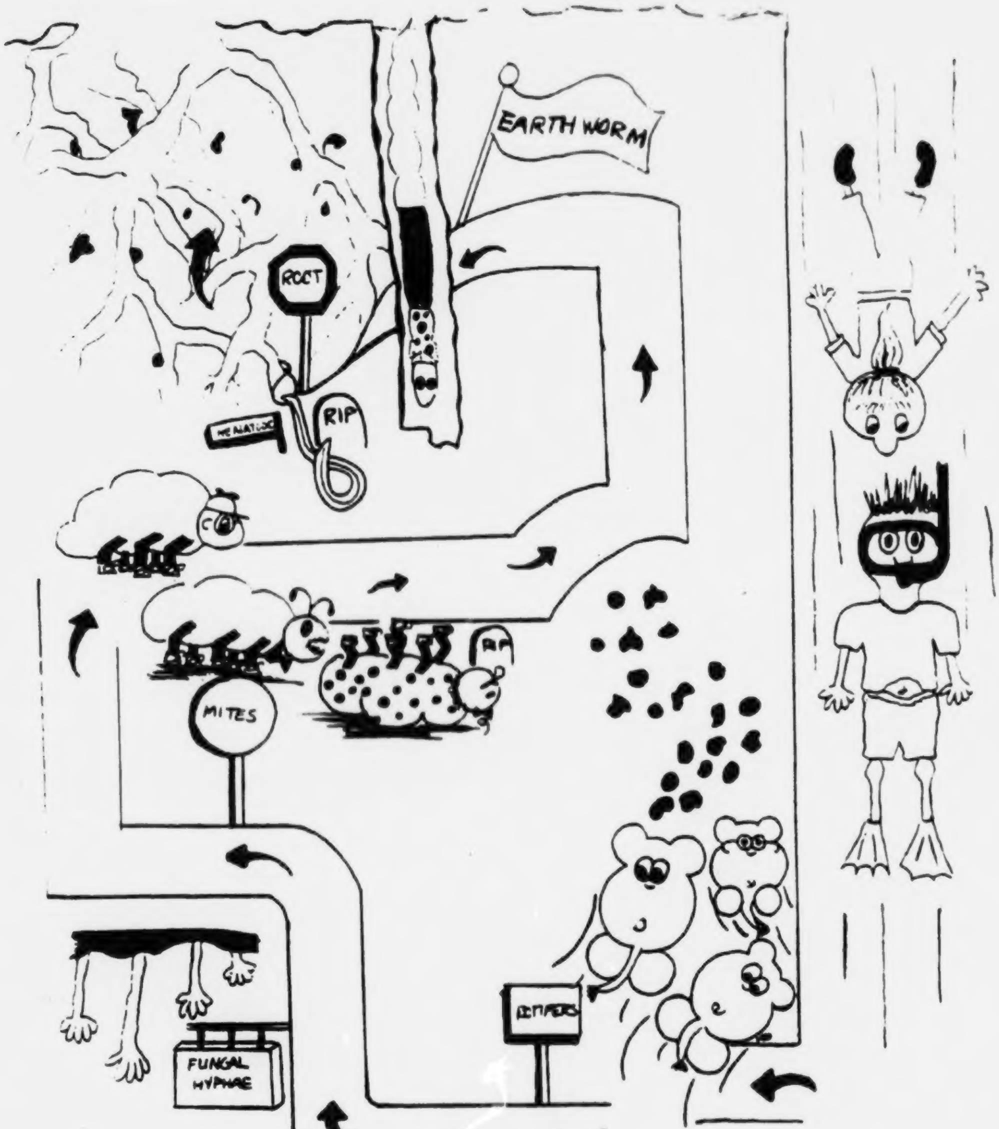
Procedure

1. Fill container with moist soil.
2. Add earthworms (10-15) to one end.
3. Place residue on opposite end.
4. Place container in a dark, cool area.
5. Add water to soil as needed to maintain suitable moisture for earthworms.
6. Observe the piles of residue over a period of time.
7. Observe the middens created by the earthworms.
8. Add a small amount of water next to a midden. Observe how the water soaks in. Repeat in an area with no middens. Why is there a difference?
9. Why has the residue moved?

Conclusions

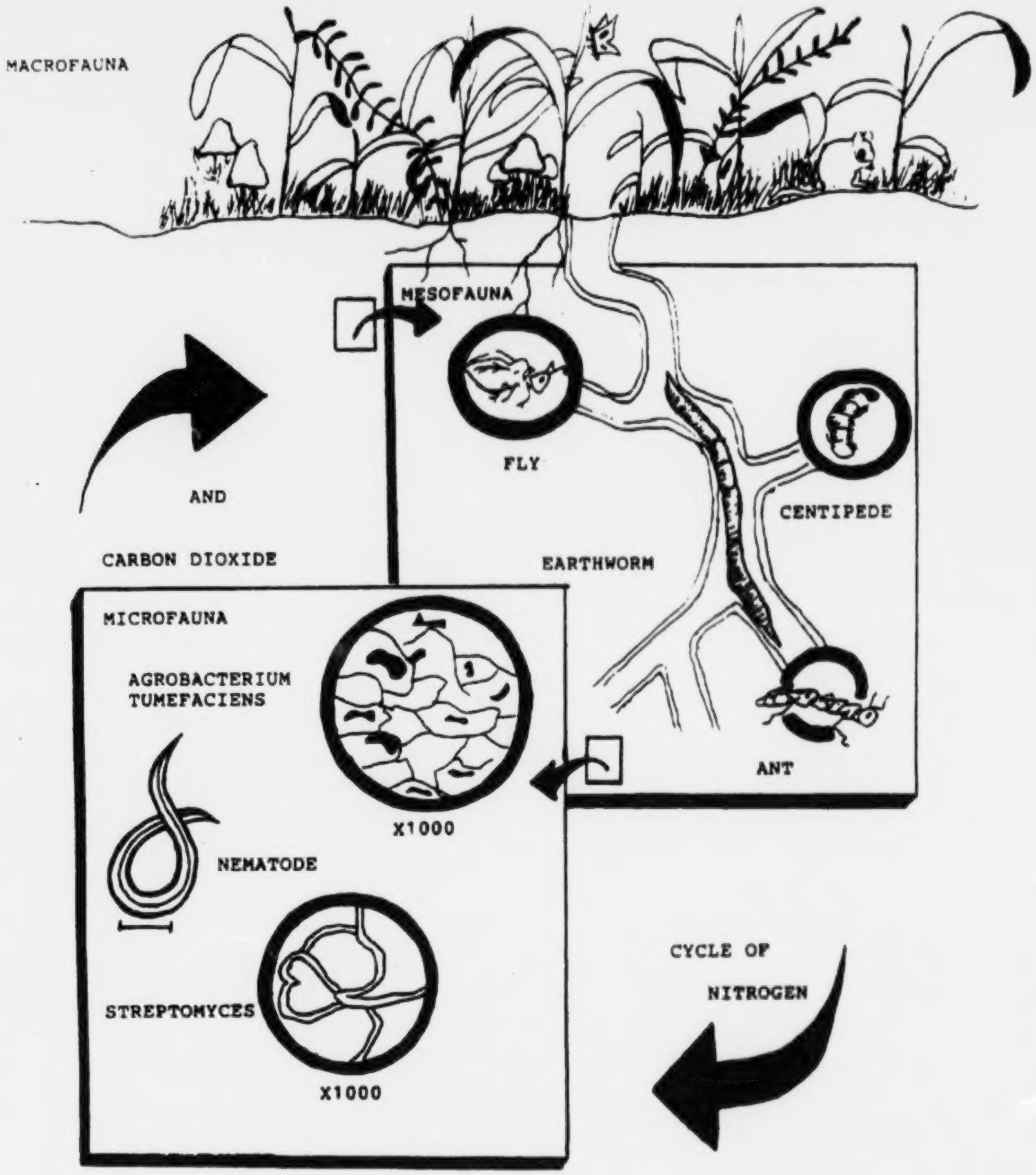
Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa, February 1992

Tour of the Underworld


EARTHWORM
ROOT
NEMATODE
RIP
RIP
MITES
FUNGAL HYPHAE
ROTIFERS

Designed by Mindy Gillespie, Iowa State University, March 1994

Earth's Recycling Factory


MACROFAUNA
MESOFAUNA
FLY
CENTIPEDE
AND
CARBON DIOXIDE
EARTHWORM
MICROFAUNA
AGROBACTERIUM TUMEFACIENS
X1000
ANT
NEMATODE
CYCLE OF
NITROGEN
STREPTOMYCES
X1000

Designed by Mindy Gillespie, Iowa State University, March 1994

Willy's Team

- Animals
  - Macro
    - Subsisting largely on plant materials
      - Small mammals-squirrels, gophers, woodchucks, mice, shrew
      - Insects- springtails, ants, beetles, grubs, etc
      - Millipedes
      - Snowbugs (woodlice)
      - Mites
      - Slugs and snails
      - Earthworms
    - Largely predatory
      - Moles
      - Insects- many ants, beetles, etc
      - Mites, in some cases
      - Centipedes
      - Spiders
  - Micro
    - Predatory or parasitic or subsisting on plant residues
      - Nematodes
      - Protozoa
      - Rotifers
- Plants
  - Roots of higher plants
  - Algae
    - Green
    - Blue-green
    - Diatoms
  - Fungi
    - Mushroom fungi
    - Yeasts
    - Molds
  - Actinomycetes of many kinds
  - Bacteria
    - Aerobic
    - Anaerobic
    - and
      - Autotropic
      - Heterotropic

Prepared by Annette Kiefer, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. June 1994

Quotable Quote - Albert Schweitzer

The deeper we look into nature, the more we recognize that it is full of life, and the more profoundly we know that all life is a secret and that we are united with all life that is in nature. Man can no longer live his life for himself alone. We realize that all life is valuable and that we are united to all this life. From this knowledge comes our spiritual relationship to the universe.

Albert Schweitzer - 1875-1965
German Philosopher, Physician, Clergyman and Musicologist
Awarded Nobel Peace Prize - 1952

Quotable Quote - Rachel Carson

REALMS OF THE SOIL

The thin layer of soil that forms a patchy covering over the continents controls our own existence and that of every other animal of the land. Without soil, land plants as we know them could not grow, and without plants no animals could survive.

Yet if our agriculture-based life depends on the soil, it is equally true that soil depends on life, it's very origins and the maintenance of it's true nature being intimately related to living plants and animals. For soil is in part a creation of life, born of a marvelous interaction of life and nonlife long eons ago. The parent materials were gathered together as volcanoes poured them out into fiery streams, as waters running over the bare rocks of the continents wore away even the hardest granite, and as the chisels of frost and ice split and shattered the rocks.

Then living things began to work their creative magic and little by little these inert materials became soil. Lichens, the rocks' first covering, aided the process of disintegration by their acid secretions and made a lodging place for other life. Mosses took hold in the little pockets of simple soil -- formed by crumbling bits of lichen, by the husks of minute insect life, by the debris of a fauna beginning its emergence from the sea.

Life not only formed the soil, but other living things of incredible abundance and diversity now exist within it; if this were not so the soil would be a dead and sterile thing. By their presence and by their activities the myriad organisms of the soil make it capable of supporting the earth's green mantle.

From Silent Spring
By Rachel Carson - 1907-1964
American Biologist, Environmentalist and Author

Summary

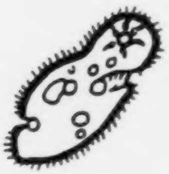
√ **In a cubic inch of fertile soil there are:**

- ☞ **10 billion bacteria**

- ☞ **1 million fungi**

- ☞ **100,000 algae**

- ☞ **10 million actinomycetes**
- ☞ **10,000 million protozoa**



Summary

√ Soil microorganisms affect the soil by:

- ☞ Converting dead plant and animal matter, and inorganic material into forms that can be used by plants or other organisms
- ☞ Producing antibiotics
- ☞ Fixing nitrogen for plants to use
- ☞ Trapping light energy
- ☞ Forming acids that dissolve minerals from rocks for plants to use

Summary

√ The earthworm is the "master builder" for farmers and gardeners, who breaks down crop residues and starts the process that allows microorganisms to finish converting the residues into forms for plants to use.

Unit II - b
Discovering the "Weavers" of the Soil: Soil Fungi

Introduction

The exercises in this part of the unit will help participants understand the importance of soil fungi in breaking down crop residues, increasing soil organic matter, and processing nutrients into a form usable by plant and animal life.

Objectives

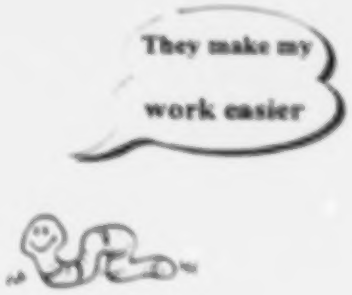
Participants will learn the importance of fungi in the soil and discover technologies for the future use of fungi in improving soil conditions. Participants also will debate the pros and cons of new efforts in research and technology.

Competencies

1. Explain the importance of beneficial fungi and plant roots.
2. Demonstrate what mycorrhizae do.
3. Describe the relationship between the plant and mycorrhizae.
4. Analyze the importance of living soil organisms in new technology.
5. Draw a picture of the root-fungi relationship.

Materials

A piece of sod, including grass, roots, soil, etc.
A bag of peanuts.
A cob of corn.
Refer to Lab Activities.


They make my work easier

Information

INFO-MICRO-6	Animal or Plant?
INFO-MICRO-7	Vocabulary Builder

Activities

ACT-MICRO-8	Knowledge Builder
ACT-MICRO-9	Improving the Environment With Fungi
ACT-MICRO-10	Reaching Out For Plant Food With Mycorrhizae
ACT-MICRO-11	Vocabulary Challenger

Laboratories

LAB-MICRO-4	Marvelling at the Microworld
LAB-MICRO-5	The Plant-Fungi Relationship

Visual Master

VM-MICRO-8	Silent Army
VM-MICRO-9	Weavers of the Soil
VM-MICRO-10	Summary

Teaching Procedure

1. As **Part A** of an **Interest Approach**, bring to class a clump of sod and ask the following question. **Why should a farmer, a golf course manager, or gardener be interested in the process of recycling organic matter?** Allow discussion. Share with the participants that recycling of organic matter takes place underground, but some of that underground activity can be very beneficial to activities above the ground.

2. To introduce the types of fungi, use handout **INFO-MICRO-6** (Animal or Plant?)

3. Follow up with **ACT-MICRO-8** (Knowledge Builder) to reinforce understanding of the types of fungi and their functions.

   Q1. Match the following terms with their correct definitions.

   A1.

l	true slime mold	d	endomycorrhizae
c	fungi	m	mushrooms
b	cellular slime mold	g	organotrophic
k	flagellate	i	imperfect
a	eukaryotic	h	higher
f	ectomycorrhizae	j	heterotrophic
e	sugar	n	hyphae

   Q2. If, by mistake, a product was developed that killed all soil fungi, what would be the consequences?

   A2. Although destruction of all soil fungi would prevent destructive types from causing problems, beneficial fungi are important in breaking down substances that cannot be broken down any further by other organisms. Fungi make possible that important transition from unusable to usable nutrients.

4. As part B of an **Interest Approach, Bring to class a bag of peanuts and an ear of corn.** Let the participants sample the peanuts, and then ask them if they would eat the peanuts if there were a fungus on them. Explain that fungi can be harmful to crops, but that there is research being done looking for ways to utilize beneficial bacteria. Follow up using **ACT-MICRO-9** (Improving the Environment With Fungi) to show them various ways fungi can affect crops -- both harmfully and beneficially. This also will introduce the value of existing alternatives to improve the environment. **This activity is a series of cases that explain some type of research being conducted, and participants should think carefully about the impact these could have.**

   Participants should review the examples of research presented in this activity. Assign groups to set up pro and con debate teams to debate the issues. Another option would be to ask the teams to prepare an advertisement to promote the sale of these new products and discuss how they could be marketed.

Case 1

Q1. Aflatoxin affects peanuts, but it also affects corn. Is any research being done to find non-toxic strain of aflatoxin for corn?

A1. Check with Extension or a member of the Iowa Corn Growers Association.

Case 2

Q2. What are the benefits of society in using this technology?

A2. It will make these products environmentally friendly by making them easier for organisms to recycle back into the soil. Environmental awareness and preservation are important social issues; this provides a way to alleviate some disposal and degradation problems.

Q3. What are the benefits to farmers of using farm products to help solve environmental problems?

A3. Farmers will have a new market for traditional crops. This will increase demand, which in turn will be profitable for farmers.

Q4. Does fungi have any role in the degradation of these materials?

A4. Fungi will play a part in the final degradation process and provide nutrients to plants.

Q5. Are there disadvantages to this technology? If so, what are they?

A5. If natural biological controls can replace more risky controls, it's a benefit to the environment. However, it takes time to develop and produce such technology, and it may take a long time before it becomes available. It may be expensive.

Case 3

Q6. How would this help the environment?

A6. Natural controls may be more environmentally sound and less harmful to living, beneficial organisms.

Q7. Are there disadvantages to this technology? If so, what are they?

A7. This system may not be as effective as other controls in solving the problem.

5 To stimulate student thought on how soil structure is affected by fungi, use **VM-MICRO-8** (Silent Army) to emphasize the value of microbes in reducing degradation of soil resources. Promote discussion with the following questions.

Q1 How do fungi help make soil suitable for plant growth?

A1 Fungi are the "weavers" of the soil, and they hold the soil together. They promote good soil structure, which, in turn, promotes plant growth. Fungi also break down many substances, thus making nutrients available for plants.

Q2 How are fungi affected by soil mismanagement?

A2 Mismanagement could kill beneficial bacteria and destroy soil structure. Many nutrients would be trapped in unusable forms. Disruption of plant roots would prevent fungi from helping plants absorb nutrients.

Q3 How can fungi be used to reduce soil degradation?

A3 Promoting the growth of soil bacteria would again help to improve soil structure.

6 Use **VM-MICRO-9** (Weavers of Soil) to illustrate various types of fungi they have studied. This will give participants an idea about the wide range of fungi species in existence.

7 Investigate soil fungi through **LAB-MICRO-4** (Marveling at the Microworld).

Explain the role fungi play in the microscopic world of soil. In short, fungal threads are "weavers" that strengthen the soil's structure, thereby helping to conserve and protect the soil against water and wind erosion. **This is important because there can be no plant life without soil. And without plant life, there can be no agriculture. These microorganisms therefore directly contribute to the food security of the world.**

Note that there are many other microorganisms exist in the soil in addition to fungi , but they are much smaller than fungi and are visible only through very expensive, high-powered microscopes.

8 Use **INFO-MICRO-7** (Vocabulary Builder) to review key terms used in the unit.

9 Fungi and plants have a special relationship. **LAB-MICRO-5** (The Plant-Fungi Relationship) demonstrates the concept of symbiosis.

Discoveries

Seedlings that were treated with nitrate or inoculated should show improved growth when compared with the control seedlings. The inoculated seedlings should show better growth than the nitrate-treated seedlings.

Conclusions

Q1 Define symbiosis.

A1 Two organisms living in close association with one another. In this case, the fungi and plants have a mutually beneficial relationship.

Q2 Farmers usually rotate their crops, alternating a crop of soybeans or alfalfa with corn on the same field. Why do they do this?

A2 The nutrients provided by the soybeans or alfalfa will give the corn the nutrients it needs for a good crop. The fungi will make these nutrients available to corn roots.

Q3 How does what you discovered in this experiment relate to profitable nutrient management?

A3 By taking advantage of the plant-fungi relationship, farmers can reduce the costs of chemical and mechanical management. A soil inoculated with fungi will help crops take up nutrients better than if only fertilizer was used.

10 Mycorrhizae are important in the symbiotic relationship between plants and fungi. Encourage participants to investigate this relationship further by using **ACT-MICRO-10** (Reaching Out For Plant Food With Mycorrhizae). Encourage them to find library resources, or provide resources for them to do their research.

Q1 Explain how endomycorrhizae live in union with a soybean plant.

A1 Endomycorrhizae function as extensions of the roots by bringing in nutrients that the root would not have received otherwise. The root provides a place for the endomycorrhizae to live.

Q2 Draw the endomycorrhizae-root relationship.

Q3 Explain the benefits of endomycorrhizae to the soybean plant.

A3 Not enough nutrients occur naturally in the soil for a legume such as the soybean to form nodules. Soybeans need to be inoculated so that they can function properly.

Q4 What are the differences between endomycorrhizae and ectomycorrhizae?

A4 Endomycorrhizae have filaments that help roots. Ectomycorrhizae form mats over the root tip.

Q5. Does Iowa soil have high populations of mycorrhizae?

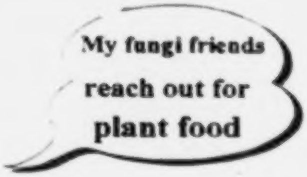
A5. Mycorrhizae are numerous in fields which contain legumes, such as soybeans and alfalfa. Iowa soils will have high populations of mycorrhizae in fields that contain such crops.

11. Use **ACT-MICRO-11** (Vocabulary Challenger) to review key terms used in the unit.
Across:
1. ectomycorrhizae 3. acrasiomycetes 4. mushrooms 7. spores 8. eukaryotic
Down:
1. endomycorrhizae 2. organotrophs 5. symbiotic 6. mycelium

12. Use **VM-MICRO-10** (Summary) to summarize Unit II-b.

Animal or Plant?

Fungi are classified as eukaryotic organisms, which include molds, mildews, rusts, smuts, yeasts, mushrooms, and puffballs. Many fungi produce different kinds of filament structures and mycelium. They grow rapidly, which allows easy penetration of substrates like leaf litter, wood, and crop residue. Soil fungi are in a group classified as organotrophs. **Their responsibilities are to decompose organic matter.** Fungi break down cellulose, hemicellulose, and lignin, which are major components in many plant materials. Soil fungi grow well in acid soils and reproduce by means of spores. Fungi are heterotrophs, and lack chlorophyll, which means that they don't use the sun for growth. They depend on carbon for their nutrition, which they get from breaking down plant residues. There are many different kinds of fungi, which will be described in the following paragraphs.


My fungi friends reach out for plant food

There are two types of **slime molds** - Acrasiomycetes and Myxomycetes.

Acrasiomycetes are **cellular slime molds**, which are found in decaying plant material. Myxomycetes are the **true slime molds**, which are animal-like in their feeding but **fungus-like in their reproduction**. Slime molds are distributed widely throughout the soil, especially in association with decaying vegetation in cool, moist sites.

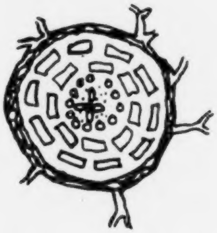
Oomycetes are a form of **flagellate fungi** and are found in water and soil. Their main form of movement is with flagella -- long, tail-like structures. Many of them are highly destructive plant pathogens, such as potato blight and grape mildew.

Zygomycetes are called **Sugar Fungi** because they ferment different kinds of carbohydrate substrates. One kind is common bread mold. In the soil, they can break down the carbohydrates in many kinds of crop residues.

Ascomycetes and basidiomycetes are called **higher fungi**. Ascomycetes include organisms such as yeasts, morels, truffles, cup fungi, powdery mildew, and common dark-colored molds. Many are parasites on plants such as root rot, corn ear rot, brown rot of stone fruit, etc. Basidiomycetes include mushrooms, puffballs, slinkhorns, bracket fungi, smuts, rusts, and jelly fungi. Many of these help rot wood, leaves, and crop residue in cool, moist areas. This breakdown creates humus, the organic matter needed in soil formation. Mushrooms, of course, are a popular food source, and growing them can be profitable.

Deuteromycetes are known as **imperfect fungi** because they lack the sexual phase of regeneration. They reproduce through breaking off the hyphae.

Mycorrhizae can be described as the beneficial relationship between plants and certain fungi. **Some plant nutrients become deficient because they move with difficulty through the soil. Development of mycorrhizae can extend the root system to catch those nutrients. A mychorrhizal fungus can bring nutrients into the plant, while at the same time getting food from the plant root.** The principal benefit of mycorrhizae is that they seem to increase the absorption of phosphorous and other soil nutrients. They also protect roots from infection by harmful fungi. **Like other fungi, millions and billions of them may be found on each plant.** This increases productivity.



Some beneficial mycorrhizae fungi live in the plant roots of most crops, including corn and soybeans. They increase the uptake of several mineral nutrients by the crop plants by growing out from the roots into soil areas where root hairs are unable to reach. The mycorrhizae then transfer those nutrients back to the root hairs.

There are two kinds of mycorrhizae: endomycorrhizae are threadlike and attach to one cell of the root. They develop in the roots of deciduous trees, most annual crops, and other herbaceous species. They tend to form colonies and are often found in the rhizosphere of soybeans. They increase the uptake of phosphorous. Ectomycorrhizae form mats over the root tip, and are found on most evergreen trees and shrubs.

Most Iowa soils contain moderate to high levels of mycorrhizae in association with increasing soybean productivity.

VOCABULARY BUILDER
Unit II - b

Cellulose, hemicellulose, lignin - the major components found in many plant materials

Flagellate Fungi - found in water and soil; move around with a tail-like structure

Heterotrophs - a class of organisms that depend on organic matter supplied by other sources, they do not produce their own food.

Higher Fungi - help in rotting wood, leaves, and crop residue in cool, moist areas.

Hyphae - the branched filaments that make the weblike body of fungi

Imperfect Fungi - fungi that reproduce by asexual means.

Mycorrhizae - the beneficial relationship between fungi and plant roots.

Organotrophs - a class of organisms that decompose organic matter, fungi are classified into this group.

Slime Molds - found in cool, moist places; process decaying vegetation into nutrients plants can use.

Sugar Fungi - break down carbohydrates for plants to use.

Symbiosis - two organisms living in close association with one another. Fungi and plants have a mutually beneficial relationship.

Weavers of the soil make my work eaiser

Knowledge Builder
Unit II - b

1. Match following terms with their correct definitions

___ True Slime Mold
___ Fungi
___ Cellular Slime Mold
___ Flagellate
___ Eukaryotic
___ Ectomycorrhizae
___ Sugar
___ Endomycorrhizae
___ Mushrooms
___ Organotrophic
___ Imperfect
___ Higher
___ Heterotrophic
___ Hyphae

(a) A classification of organisms that means they have more than one cell and have a distinct nucleus.
(b) The fungi that is found in decaying plant material.
(c) A soil organism that helps plant roots reach farther into the soil for nutrients.
(d) Threadlike fungi that are attached to one root cell.
(e) Fungi that ferments different kinds of carbohydrates.
(f) Fungi that form mats over the tips of plant roots.
(g) The main responsibility of this fungus is to decompose organic matter; it is classified as __________.
(h) A type of fungi that are parasites on plants, and include yeasts, powdery mildew, and various molds.
(i) Imperfect fungi that reproduce by breaking off of hyphae.
(j) Fungi that lacks chlorophyll is classified as ____________.
(k) Fungi that can be found in water and move with a long tail-like structure.
(l) The fungi that feeds in a way similar to an animal.
(m) A type of higher fungi that help rot wood, leaf and crop residues and prefer cool, moist areas.
(n) Long, trailing filaments that help fungi weave the soil.

2. If, by mistake, a product was developed that killed all soil fungi, what would be the consequences?

3. Using your imagination, draw a picture of the root-fungi relationship (as viewed from a powerful microscope).

Improving The Environment With Fungi

Case 1 - Toxins in Peanuts and Corn

A cousin of my fungi friends can be harmful

When peanuts are being grown, producers need to be aware of fungi called *Aspergillus parasiticus* and *Aspergillus flavus*. These strains can be infected with a natural toxin known as aflatoxin, which makes the peanuts inedible. Some strains of this fungi infect corn and make it unusable for feeding humans and animals.

Prevention of the occurrence of this toxin is important; research is being conducted to investigate the existence of beneficial fungi to eliminate the dangers of aflatoxin. Aflatoxin contamination costs the nation's peanut growers an estimated $25 million annually, according to the Peanut Advisory Board in Atlanta, Georgia. The peanut industry's goal is to eliminate this potent natural toxin by the year 2000. "The only known methods for controlling preharvest aflatoxin contamination in peanuts are irrigation or early harvest," says Richard J. Cole, a co-inventor and research leader at the Agriculture Research Service's National Peanut Research Laboratory in Dawson, Georgia. However, scientists have discovered an *A. parasiticus* fungus strain that does not produce aflatoxin. **The toxin-producing strains found naturally in soil would be replaced by the non-toxin-producing strain that is added to the soil. Peanuts subjected to late-season drought stress would be invaded predominately by the competitive fungus, which doesn't produce aflatoxin.**

When harvesting a peanut crop, the U.S. Food and Drug Administration requirements state that grain and finished products with 20 parts per billion or more of aflatoxin can not be sold for human consumption or animal feed, with certain exceptions. One part per billion is equivalent to less than one drop in 10,000 gallons. **This makes the non-toxic strain of the aflatoxin fungus very important to the peanut industry.** This fungus was tested for three years before it was approved for use, and probably won't eliminate aflatoxin contamination completely. However, when it is used with other available techniques, it could go a long way toward ensuring an aflatoxin-free supply of edible peanuts.

1. Aflatoxin affects peanuts, but it also affects corn. Is any research being done to find non-toxic strain of aflatoxin for corn?

Background:

The Agriculture Research Service (ARS, January 1 - March 31, 1994, quarterly report) contained the following information as examples of research with living organisms designed to improve our environment in the future.

Source: Cole, Richard J. "Pitting Fungus Against Fungus". Agricultural Research. USDA - Agricultural Research Service. May 1992
Adapeted by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa

Case 2 - From Dust to Dust

Americans are accustomed to using plastics that are not biodegradable (not easily recycled back to the soil). Make cups, plates and packaging from potato and corn starch. These materials are made from 100 percent starch-based foam that will be recycled back to soil through the interaction of microorganisms. Microbes consume the starch-based products, transforming them into nutrients and soil organic matter.

2. What are the benefits of society in using this technology?

3. What are the benefits of farmers in using farm products to help solve environmental problems?

4. Do fungi have any role in the degradation of these materials?

5. Are there disadvantages to this technology? If so, what are they?

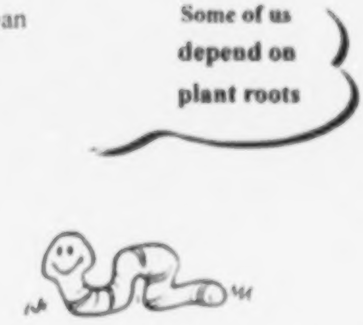
Case 3 - Living Organisms in Pellets

ARS scientists invented technology to formulate a fungus (*Gliocladium*) into easy to apply pellets. They are exploring ways of combining the pellets with fertilizer to protect ornamental and flowers from "damping off" diseases of seeds or seedlings.

5. How would this help the environment?

Reaching Out For Plant Food With Mycorrhizae
Worksheet

1 Explain how endomycorrhizae live in union with a soybean plant


Some of us depend on plant roots

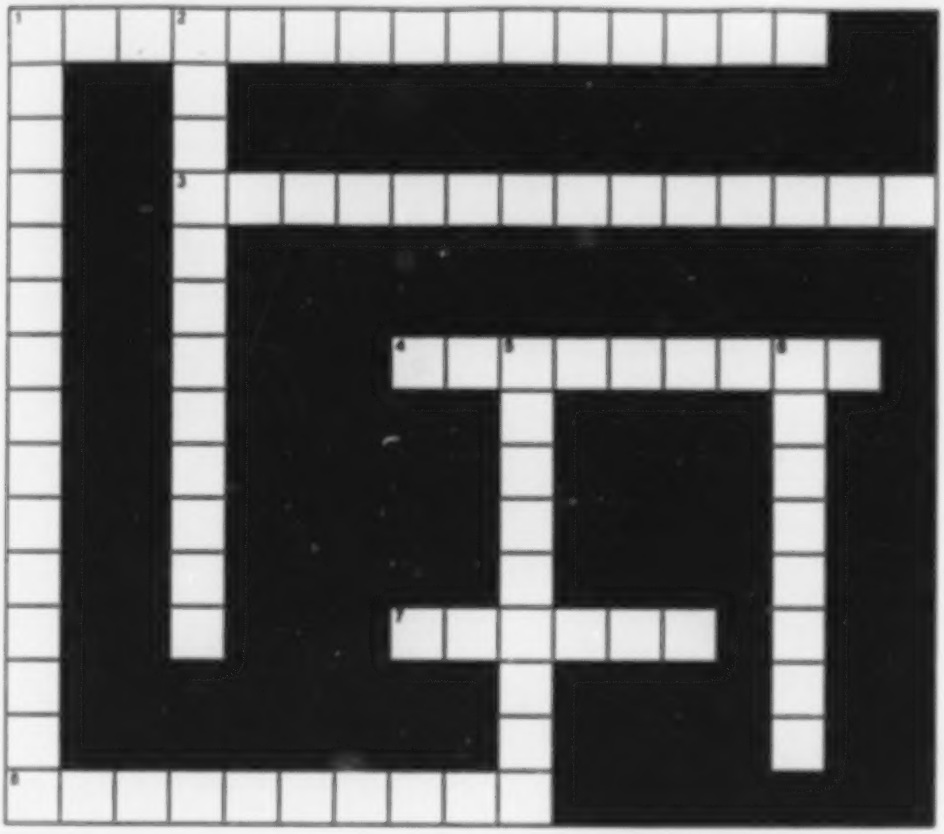
2 Draw how you think endomycorrhizae live in union with the root of a soybean plant

3 Explain the benefits of endomycorrhizae to the soybean plant

4 What are the differences between endomycorrhizae and ectomycorrhizae?

5. Does Iowa soil have high populations of mycorrhizae? Explain

Vocabulary Challenger - Unit II - b



ACROSS

1 Form mats over the root tip.
3 Are the cellular slime molds found in decaying plants.
4 Basidiomycetes include puffballs, stinkhorns, and _____
7 Soil fungi reproduce asexually by _____
8 Fungi are _____ organisms.

DOWN

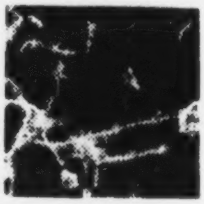
1. _____ are threadlike and attach in one cell of the root.
2. Soil fungi are in the group of _____
5. Mycorrhizae is described as a _____ relationship with plant roots.
6. Many fungi produce different kinds of filament structures called _____

Prepared by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. April 1994

Marveling At The Microworld

Introduction

Many organisms in the soil cannot be seen with the naked eye. Discover the soil's microscopic world firsthand! During this activity the invisible becomes visible! Microscopes and hand lenses can be used to see fungi in the soil.



Who will be first to find fungi--the white threadlike microorganisms pictured in the photo ? (Photo by Hari Eswaran, magnified 25,000 times with a scanning electron microscope.)

Objective

Participants will be able to locate and identify fungi in topsoil and subsoil.

Competencies

1. Utilize microscopes and hand lenses.
2. Determine the soil type that fungi prefer.

Materials (for the class)

1. Small shovel.
2. Large spoon.
3. Two small paper bags per student.
4. Colored pencils.
5. Drawing paper.
6. Several hand lenses or classroom microscopes.

Gathering Samples

1. Distribute two small paper bags to each student. Instruct participants to label one bag "topsoil" and the other "subsoil."
2. Escort the class to any area where it is possible to dig topsoil. Scoop up a shovelful of the uppermost layer of soil, two to three inches deep. Spoon a small sample into each participant's bag labeled "topsoil."
3. Find an area with bared subsoil--a construction site or road cut, for example. Dig soil that is 10 to 12 inches deep, and spoon small samples into participants' bags labeled "subsoil."
4. Return to the classroom.

If it is inconvenient to bring the class to dig soil samples, you could collect the samples in advance. Dig one shovelful each of topsoil and subsoil and put them in large paper bags. When class begins, hand out bags, have participants label them, and distribute soil samples in the classroom.

Marveling at the Microworld

1. After returning to the classroom, use a microscope or hand lens to compare the two soil samples, and draw what you see.

2. Look at the photo of fungal threads (see photo), then look again at your samples with the hand lens or microscope. Can you find these fungi in your sample? Students will discover that fungi are found mainly in topsoil, and some subsoil samples may have no fungi at all.

3. When one or more students find fungi, take turns viewing the fungi and drawing what you see.

Extensions

Using your eyes or a classroom microscope or hand lens, you can observe several other aspects of soil science:

1. the color of soil;
2. how soil particles are clustered;
3. the size and shape of clusters (fine or coarse);
4. the size and shape of roots. (Some roots are as delicate as silk thread to the naked eye, but appear to be massive, gnarled tree trunks under the microscope).

For resource material about the many aspects of soil science, contact your Soil Conservation Service (SCS) field office, listed in your local telephone directory under United States Department of Agriculture. There are approximately 3,000 SCS field offices, one in nearly every county in the United States.

Source: "Find the Fungi". Science Scope Magazine. February 1993.
Adapted by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa.

The Plant-Fungi Relationship

Introduction

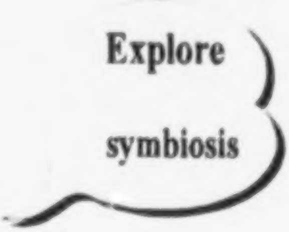
Some species of bacteria live in harmony with other organisms. This condition is called *symbiosis*, which means that the relationship benefits both organisms involved. This relationship exists between legumes (alfalfa, clover, soybeans, etc.) and the bacteria of the genus *Rhizobium*.

Objective

Participants will be able to observe and explore *Rhizobium* bacteria and their relationship to plant roots, and will compare the effects of nutrient sources on plant germination and growth.

Competencies

1. Determine how bacteria and fungi benefit each other.
2. Determine the symbiotic relationship using treatments and controls.
3. Explain the concept of symbiosis.
4. Compare nutrient sources by observing their effects on plant germination and growth.



Materials

1. Fresh soybean plant, with roots carefully removed from the soil.
2. Glass microscope slides.
3. Microscope.
4. Methylene blue stain.
5. Nine small flowerpots that contain similar soil.
6. Oven or autoclave.
7. Soybean seeds (soaked for 24 hours in water).
8. Sodium nitrate, ten grams.

Procedure

1. Carefully wash the roots of the soybean plant, and see the nodules.
2. Crush a nodule between two glass slides.
3. Place a thin layer of this tissue, along with a drop of water, on a slide and cover it with a coverslip.
4. At the edge of the coverslip, add a drop of methylene blue stain. Watch the staining of the bacteria through a microscope (high power).
5. Sterilize the soil in all of the pots in an oven or autoclave.
6. Add two grams of sodium nitrate to three of the pots; be sure to label them.

7. Crush six nodules from the soybean plant. Suspend them in water, then use this solution to treat three more pots with this suspension. This process is called **inoculation.** Label these pots.
8. Label the last 3 pots as controls.
9. Add to all the pots an equal number of soaked soybean seeds. Slightly cover the seeds with soil.
10. Place the pots in a sunny location and water with equal quantities of water, as needed.
11. Observe the pots for two weeks and record your results.

Discoveries

1. Make a series of comparisons:
    a.) the control seedlings vs. those in the nitrate-treated soil
    b.) the control seedlings vs. those in the inoculated soil
    c.) the seedlings in the nitrate-treated soil vs. those in the inoculated soil

Can you account for the differences?

Conclusions

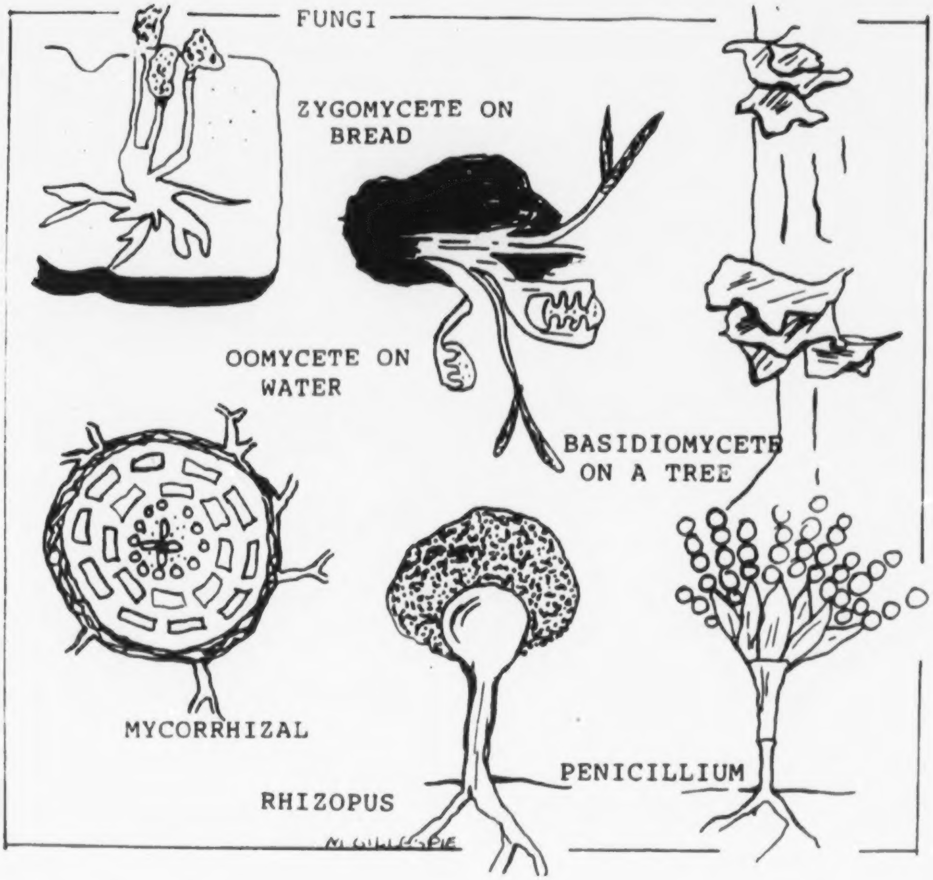
1. Define symbiosis.
2. Farmers usually rotate their crops, alternating a crop of soybeans or alfalfa with corn on the same field. Why do they do this?
3. How does what you discovered in this experiment relate to profitable nutrient management?

Source: Andrews, William A., Editor. **A Guide to the Study of Soil Ecology**. Prentice-Hall, Inc. New Jersey. 1973
Adapted by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1994

"Soil-borne microorganisms and earthworms are the silent army that has, since time immemorial, worked not only to make the topsoil a suitable medium for plant growth, but also has helped to temper the degradation of the soil through erosion and other forms of mismanagement by some human beings."

Hari Eswaran
National Leader, World Soil
Resources
Soil Conservation Service
United States Department of
Agriculture
Washington, D.C.

Weavers of the Soil


FUNGI
ZYGOMYCETE ON BREAD
OOMYCETE ON WATER
BASIDIOMYCETE ON A TREE
MYCORRHIZAL
RHIZOPUS
PENICILLIUM
M. GILLESPIE

Designed by Mindy Gillespie, Iowa State University, Ames, Iowa. April 1994

Summary

√ There are many different types of fungi and each is found in different environments.

They include:

☞ Slime molds
☞ Flagellate fungi
☞ Sugar fungi
☞ Higher fungi
☞ Imperfect fungi
☞ Mycorrhizae

Summary

- √ Fungi exist in leaf litter, wood, and crop residue.
- √ Mycorrhizae have a symbiotic relationship with plant roots, because they aid roots in absorption of minerals and also protect roots from harmful fungi.

Summary

- √ Iowa soils contain large amounts of mycorrhizae that improve soybean production.

- √ Fungi weave threads in the soil that strengthen soil structure and also conserve and protect the soil against water and wind erosion.

Unit II - c
Recognizing the Importance of Bacteria in Recycling of Soil Nutrients

Introduction

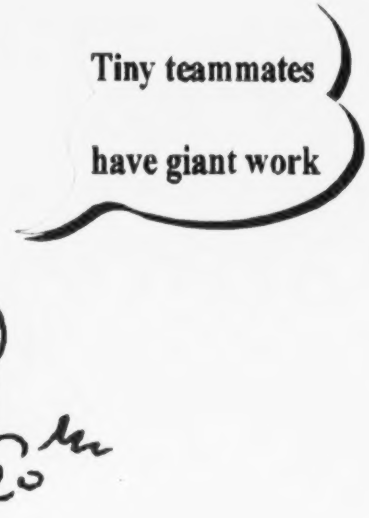
Soil-borne bacteria play a major role in decomposing crop residues, leaves from trees, wood, and any other living matter on the surface of the soil. The effects of their activities can be detected by determining soil health. Their activities cannot be noticed without careful observation.

Objective

Participants will observe living bacteria in relation to what might be in the soil, discover the characteristics of soil health, and analyze the value of soil bacteria in new technology.

Competencies

1. Complete transfer of live bacteria.
2. Observe the growth of live bacteria.
3. Observe a live bacterium.
4. Analyze the value of nitrogen-fixing bacteria in soybean growth.


Tiny teammates have giant work

Materials

Legume plant with nodules
Refer to lab activities

Information

INFO-MICRO-8	Living Bacteria in the Soil
INFO-MICRO-9	Vocabulary Builder

Activities

ACT-MICRO-11	Soil Health
ACT-MICRO-12	"Observing Bacteria" Worksheet
ACT-MICRO-13	Knowledge Builder
ACT-MICRO-14	Bacteria for Weed Control
ACT-MICRO-15	Biological Treatment of Wastes
ACT-MICRO-16	Underground Plant and Animal Relationship
ACT-MICRO-17	Vocabulary Challenger

Laboratories

LAB-MICRO-6	Observation of Living Bacteria
LAB-MICRO-7	Bacteria Growing
LAB-MICRO-8	Composting: Getting Those Microbes in Gear!

Visual Master

VM-MICRO-11	Teammates
VM-MICRO-12	Summary

Procedure

1 As an **Interest Approach**, use a Petri dish with some kind of bacteria growing on it. Pass it around, but be careful not to open it. Materials can be ordered from Wards Biology Catalog (1-800-962-2600) or any other biological supplier.

Ask the following questions:

- What comes to your mind when you think of bacteria? Answers will vary.
- Where do bacteria exist? Almost everywhere.
- Are bacteria harmful or beneficial? Some types are harmful, some are beneficial.
- Can bacteria be used to improve the soil? How?

Bacteria can be used to control pest species. The bacterium contained in the Petri dish is a beneficial type that could kill pests such as: celery looper worm, cabbage loopers, tomato and tobacco hornworms, cotton bollworms, and tobacco budworms that eat tobacco, cotton, tomatoes, garden peas, and other crops; southwestern and European corn borers, codling moths that damage apples, pears, and walnuts; also diamondback moths and imported cabbageworms that are pests of cabbage, broccoli, and other crops.

These bacteria are naturally occurring microbes known to cause the celery looper virus, they might be purified, then packaged, and sold as an environmentally friendly viral insecticide, or **biopesticide**. In this example, this biopesticide is being used to kill the hornworm caterpillars that feed upon tomato plants.

Ask the following questions:

- Have you ever heard about biopesticides?
- Have you ever used them or known someone who has used them?
- Why do you think so much research has been done on biopesticides? Concern about chemical pesticides is growing, especially when considering fruit and vegetable crops and biological controls are becoming more important.

2 Provide participants with a copy of **INFO-MICRO-** (Living Bacteria in the Soil) to identify bacteria types and to give background information needed for other activities. To visualize this information, use **VM-MICRO-** (Teammates).

Ask participants to further research the value of bacteria and prepare a one-page report on their findings.

3 Use **INFO-MICRO-** (Vocabulary Builder) to review key terms for this unit.

4 Use **ACT-MICRO-** (Soil Health) to get participants to identify bacteria's role in soil health and to illustrate new soil related technology with microorganisms.

Q1 Name the characteristics of a healthy soil, and tell why you think each characteristic is important for producing and sustaining plant and animal life.

A1. Characteristics of a healthy soil should include aggregates rather than single grains of soil, good air- and water-holding capacity, and high levels of organic matter and living soil organisms.

Q2. What role do bacteria play in a healthy soil?

A2. Bacteria decompose plant residues, animal wastes, and organic compounds, which can then become part of the soil. They help with the aggregation of the soil, which will hold water and is ideal for plant roots. Bacteria also converts elements into usable forms, making the soil more fertile, and supporting plant growth.

Q3. How could a "soil health meter" be used to help a farmer or gardener manage his/her soil and crops?

A3. The meter would help the farmer/gardener be aware of bacterial activity, and then plan accordingly when using fertilizer, pesticides, etc. If the reading is not high, indicating poor soil health, plans could be made to improve conditions for bacterial growth.

5. After participants have an idea about the importance of bacteria to the soil and nature, use **LAB-MICRO-** (Observation of Living Bacteria) to explain the effects that soil bacteria have in decomposing crop residues, leaves from trees, wood, and any other living matter on the surface. Record data using **ACT-MICRO-** ("Observing Bacteria" Worksheet).

Q1. Explain in detail the important eight steps in making a bacterial transfer.

A1.
- a. Disinfect all surfaces.
- b. Disinfect hands.
- c. Obtain one test tube sample each of Escherichia coli and Bacillus subtilis.
- d. Heat inoculating needle in flame until red-hot.
- e. Keep test tubes steady and remove plugs.
- f. Hold tube in horizontal position. Use needle to do the transfer. The needle should be inserted in the uppermost, middle, and lower regions. The transfer can be done by moving the needle slowly and gently across a fresh agar surface.
- g. Sterilize the mouth of the test tubes.
- h. Replace the plugs.

Q2. Why are soil bacteria important to agriculture?

A2. Bacteria are important because they provide an essential link in nitrogen fixation. Nitrogen becomes available to the soil and plants from the activity of *Rhizobium*. Bacteria decompose materials and convert nutrients to improve soil structure and plant growth.

6 Provide participants with **ACT-MICRO-** (Knowledge Builder) to review important terms

Q1 Match the following terms with their correct definitions

A1 i Assimilation
k Oxygen
h Autotrophic
j Carbon Dioxide
d Cultivation
g Heterotrophic

a Bacilli
f Rhizosphere
b Cocci
c Spirilla
e Biochemical

Q2 Where are soil bacteria most active? What type of activity takes place?

A2 The rhizosphere. They are very active in the part of the rhizosphere that is closest to the root surface. The activity is between the root and the bacteria, not between bacteria and other soil organisms. The bacteria help the roots attain nutrients and the roots provide an environment for bacteria to live.

Q3 How are bacteria found in the soil?

A3 They are found either in colonies or in chains of individual cells.

7 To stimulate thought on the various uses of bacteria and new technology, choose any of the following activities

ACT-MICRO- (Bacteria for Weed Control)

Q1 If this technology is developed, what are the benefits?

A1 Major reductions in crop losses and costs of chemical controls. Promotion of biological controls.

Q2 Will this have an adverse effect on chemical companies presently producing the chemicals used on leafy spurge, or will companies start developing and selling the new technology?

A2 Until the biological control is safe and approved, a market will probably still exist for the chemicals. If the chemical companies want to stay on the cutting edge, however, research needs to be done, and these companies will adapt accordingly.

ACT-MICRO- (Biological Treatment of Wastes)

Q1 Do you know of other plants that would survive pesticide-contaminated soil as well as promote an active force of microbes?

A1 This could be researched through the Soil Tilth Laboratory at Iowa State University

Q3 Are there other examples of this technology currently being used or researched?

A3 This could be researched through the Soil Tilth Laboratory at Iowa State University

ACT-MICRO- (Underground Plant and Animal Relationship) will further demonstrate the value of microbes (A legume will be needed for this activity, including roots and nodules)

Q2 Do healthy plants have more or larger nodules? Why?

A2 Yes, there is a close correlation between a vigorous, healthy root system and the above-ground plant There will be many more nodules, which supply the plant with nutrients Unhealthy plants do not have as many nodules, and do not benefit

This will generate a discussion on substituting biological for chemical control of various problems

8 Bacteria grow in any number of conditions **LAB-MICRO-** (Bacteria Growing) will show the soil environment that bacteria prefer

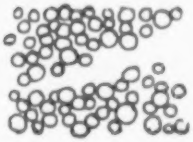
9 Bacteria have an essential role in the breakdown of waste materials in a compost pile **LAB-MICRO-** (Composting Getting Those Microbes in Gear!) This exercise will require an extended period of time It could be done during a semester, or could be provided for participants to try at home

10 Use **ACT-MICRO-** (Vocabulary Challenger) to review key terms for the unit

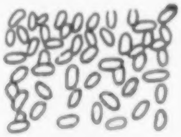
11 Use **VM-MICRO-** (Summary) to summarize Unit II-c

Living Bacteria In The Soil

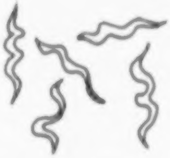
Bacteria are the most common and numerous of all microorganisms in the soil. Bacteria are single-celled organisms, representing one of the simplest and smallest forms of life. The amount of organic matter and the soil type have an important influence in the number of bacteria found in the soil. Bacteria may be classified in two ways. One is through their biochemical reactions, or the way they react to other substances. The other is through their morphology, or shape. When viewed under the microscope, most bacteria have round, rod-like, or spiral forms. The rod shapes are the most predominant in soils. Some are shown here.



Cocci



Rod-Shaped

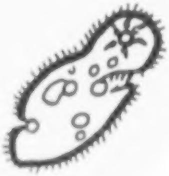


Spirilla

Bacteria are very complex organisms, because they can exist under a wide range of soil conditions. Bacteria exist by themselves or in colonies on and around soil particles, where food is available and conditions are favorable. When soil water conditions are good, some bacteria can move around very easily and swim freely. The most active site for bacteria is the rhizosphere, the zone immediately surrounding plant roots.

Most bacteria are classified according to what they need to live, such as oxygen and other nutrients. Bacteria that require oxygen-rich soils are **aerobes**, while those that don't need oxygen are **anaerobes**. Others may function under low oxygen conditions. Some bacteria are dependent upon nutrients to produce vitamins or enzymes or to break down organic molecules that they are not able to attack. Some bacteria cause disease in animals, humans, and plants, but only become dangerous if conditions are favorable.

Bacteria also are classified according to their energy sources. **Heterotrophs** are known as decomposers, and receive their energy from organic carbon in the soil. Their food is received from plant residues, animal wastes, or organic compounds. When these are added to the soil, heterotroph populations can explode.

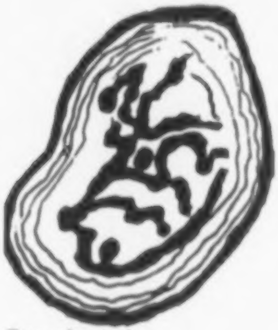


Protozoa

Bacteria

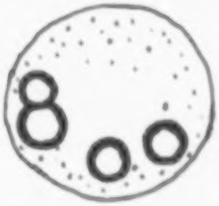
Fungi

Autotrophs get their energy from elemental or mineral elements, such as ammonium, sulfur, and iron. They can use the carbon from carbon dioxide gas as a carbon source rather than obtaining it from organic residues. Autotrophs are important in the cycling of vital plant nutrients, such as nitrogen, sulfur, and iron by making these nutrients available for plants to use. Some examples of autotrophs are as follows



Cyanobacteria

Green Plant



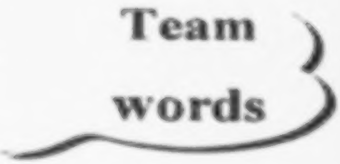
Algae

VOCABULARY BUILDER
Unit II - c

Aerobic (aerobe) - bacteria that require oxygen to live

Anaerobic (anaerobe) - bacteria that live without oxygen

Bacteria - single-celled organisms that break down substances plants can use



Autotroph - bacteria that get energy from elements in the atmosphere

Heterotroph - bacteria that are decomposers and get energy from carbon

Inoculation - the introduction of nodule-forming bacteria into the soil, especially for nitrogen fixation

Nitrogen fixation - the process of converting atmospheric nitrogen into forms plants can use

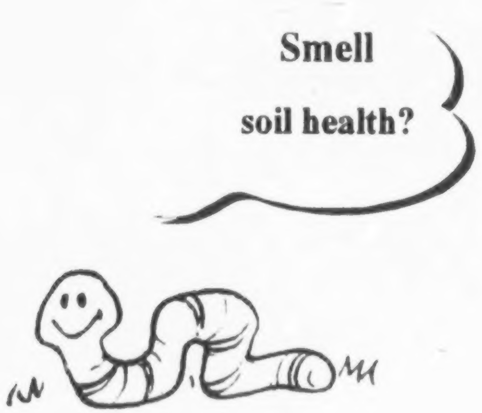
Rhizobium - a species of nitrogen-fixing bacteria that depends on the root nodules of legumes to survive

Rhizosphere - the zone immediately surrounding plant root, the most active site for bacteria

Soil Health

What is Soil Health?

1. Name the characteristics of a healthy soil, and tell why you think each characteristic is important for producing and sustaining plant and animal life.



2. What role do bacteria play in a healthy soil?

Background

The National Soil Tilth Laboratory at Ames, IA, is experimenting to determine whether soil health can be measured by odor. A healthy, fertile soil puts out an earthy odor that scientists are analyzing so they can give farmers a "measuring stick" of how rich -- or poor -- the soil is. The smell comes from compounds produced by soil microorganisms as they break down dead plants and organic matter. The compounds are produced by soil fungi and filamentous bacteria called actinomycetes. In preliminary tests, more than 20 times as much of the compound was measured in virgin woodland soil than as cropland. If this technology is developed, soil readings of the "earthy odor" could be taken by a meter for an on-the-scene analysis of soil health.

3. How could a "soil health meter" be used to help a farmer or gardener manage his/her soil and crops?

Prepared by Eldon Weber, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1994

Observing Living Bacteria Worksheet

1. Explain in detail the important 8 steps in making a bacterial transfer

   a.

   b.

   c.

   d.

   e.

   f.

   g.

   h.

2. Why is soil bacteria important to agriculture?

3. In one paragraph, summarize your experience in this exercise. Did you discover any unexpected results?

Knowledge Builder
Unit II - c

1. Match the following terms with their correct definitions

___ Assimilation
___ Oxygen
___ Autotrophic
___ Carbon Dioxide
___ Cultivation
___ Heterotrophic
___ Bacilli
___ Rhizosphere
___ Cocci
___ Spirilla
___ Biochemical

(a) Rod-shaped bacteria, the most numerous in the soil.
(b) Spherical-shaped bacteria.
(c) Spiral-shaped bacteria, not very common in the soil.
(d) These practices can affect the type and number of bacteria in the soil.
(e) Environmental condition greatly affect these types of bacterial reactions.
(f) The environment under the influence of plant roots.
(g) Bacteria that require already existing nutrients as a carbon and energy source.
(h) Bacteria that obtain energy from sunlight or by oxidation of inorganic materials.
(i) The process of converting residues into a carbon source for bacteria and other microbes.
(j) Bacteria release this gas during the decomposition of organic matter.
(k) This presence of this gas determines whether bacteria are aerobic or anaerobic.

2. Where are soil bacteria most active? What type of activity takes place?

3. How are bacteria found in the soil?

ACT-MICRO-14

Bacteria For Weed Control

Bacteria that live in the roots of leafy spurge may turn out to be enemies of this deep-rooted weed, which has been hard to wipe out. Crop losses and chemical controls cost about $35 million a year. ARS scientists have identified two beneficial bacteria that overproduce several plant hormones, harming the weeds in the process. When the bacteria were turned loose on leafy spurge seedlings in the greenhouse, seedling emergence and root length were reduced by 50%.

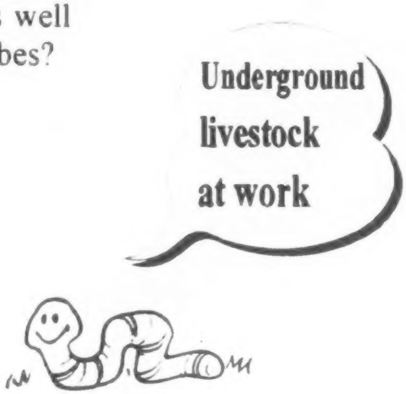
1. If this technology is developed, what are the benefits?

2. Will this have an adverse effect on chemical companies which are presently producing the chemicals used on leafy spurge, or will they start developing and selling the new technology?

Biological Treatment of Wastes

Bacteria and fungi are used in wastewater treatment and composting. If microbes are hungry enough, or you provide the right environment for them, they will degrade just about anything, including pesticide spills. It is important to develop an environment within the contaminated area that has a high population of microbes. The area around plant roots (the rhizosphere) has up to 1,000 times more microorganisms than the same soil without plant roots. Plants secrete lubricants to help their roots push through the soil. The lubricants attract a dense community of microbes, which, incidentally degrade pesticides as they eat and digest other organic matter. Researchers are working with crabgrass that has a fibrous root system, ability to retain moisture, and provides a good environment for microbes as a potential grass to seed in contaminated areas.

1. Do you know of other plants that would survive pesticide-contaminated soil, as well as promoting an active force of microbes?



2. Draw a picture of your perception of using this technology to clean up pesticide-contaminated soil.

3. Are other examples of this technology currently being used or researched?

Prepared by Eldon Weber, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1994.

Underground Plant and Animal Relationship

Nitrogen-fixing plants (alfalfa, clover, soybeans, and some trees) pull nitrogen from the air through animal life (microbes) that live in root nodules. They convert the nitrogen into plant food. The legume root nodules need nitrogen-fixing bacteria, and the bacteria need the plant root nodules. This is called symbiosis (bacteria and plants living together, which are dependent on each other).

1. Examine the root nodules of a legume plant.

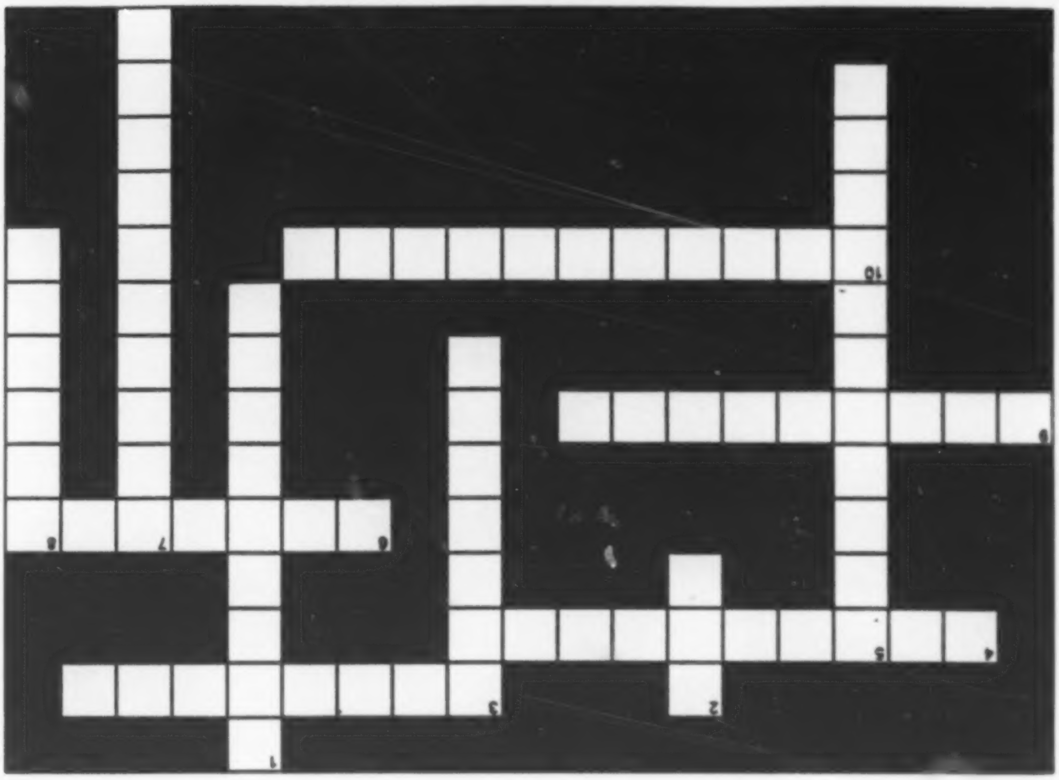
Some of my teammates live together with plants

2. Do healthy plants have more or larger nodules? Why?

3. Experiment with soybeans planted in soil with little or no nitrogen fixing-bacteria (inoculant), and soil where you have added the soybean inoculant.

Prepared by Eldon Weber, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1994

Vocabulary Challenger - Unit II - c



ACROSS

3 Bacteria can exist by themselves or in _____.
4 Bacteria can be identified by their _____, or shape.
6 An organism is _____ if it requires oxygen to live.
9 Bacteria that get energy from elements of the atmosphere are classified as _____
10 Bacteria that get energy from carbon are classified as _____

DOWN

1 Bacteria that need oxygen to survive are _____.
2 This is the shape of most soil bacteria.
3 Autotrophs are important for the _____ of vital nutrients.
5 The zone immediately surrounding plant roots that is the most active site for bacteria.
7 These reactions show how bacteria react with other substances.
8 This element is the result of decomposition.

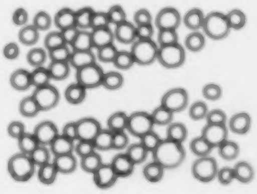
Observation of Living Bacteria

Introduction

Bacteria is often considered dangerous -- things that cause illnesses and diseases. Soil bacteria are beneficial, however, because they contribute to the process of nutrient recycling. To be able to see these bacteria in action will promote understanding of their importance.

Objective

Participants will be able to isolate living bacteria from the soil and observe them under a microscope.



Competencies

1. Differentiate between two types of bacteria.
2. Complete a transfer of bacteria.
3. Identify characteristics of living bacteria.

Materials

1. Cultures of Bacillus subtilis and Escherichia coli. Use commercially prepared, dehydrated broth. Follow the directions on the package. Wards Biology Catalog (1-800-962-2600) or any other biological supplier will have the cultures.
2. Compound microscope
3. Bunsen burners
4. Coverslips
5. Depression slides
6. Inoculation loop
7. Toothpicks or dissecting needle
8. Fresh agar slant in test tubes
9. Labels
10. Two test tubes of tap water
11. Lens paper
12. Disinfection solution
13. Antiseptic (hand soap)
14. Petroleum jelly

Procedure

Making a sterile bacterial transfer.

1. Make sure all surfaces to be worked on, or with, are disinfected.

2. Make sure your hands are scrubbed. (Note: if any bacteria are spilled, pour disinfectant on the area quickly. Then let it stand for 30 minutes).

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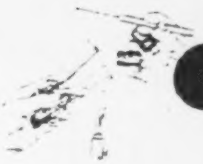
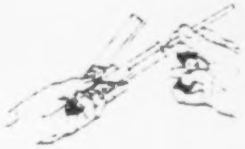
3 Obtain the two test tube samples (colonies) containing Escherichia coli (white, thick growth) and Bacillus subtilis (gray and shiny growth)

4 Hold the inoculating needle in the flame of a Bunsen burner until it is red hot



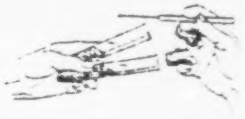
5 Use your thumb to hold the test tube steady in one hand Remove the plugs with the thumb of the other hand

6 Position the needle in the culture to pick up and transfer bacteria Insert the needle and gently touch the tip in the uppermost, middle, and lower regions. Transfer a small amount of culture by carefully and gently moving the needle across the fresh agar surface. Keep the tube in a horizontal position during the transfer to prevent contamination of the agar from air particles



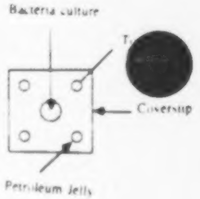
7 Reflame the mouths of the test tubes to sterilize the end

8 Replace the plugs



Preparing a Hanging Drop Slide

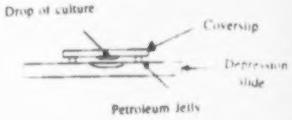
1 Using a dissecting needle or toothpick, add a dot of petroleum jelly to each corner of a coverslip. Suspend the needle slightly above the coverslip and let a small drop fall off in each corner.



2 Use the sterile technique to transfer a bead-like drop of the liquid bacterial culture to the center of the coverslip.

3 Carefully place a very clean depression slide over the coverslip. The depression in the slide should face the coverslip over the bacteria.

4 Carefully and quickly flip the slide over so that the drop hangs freely.



5 Look at the slide under the microscope. First, use low power to center the bacteria with the lens, then go to high power. You should be able to see the living bacteria.

Adapted by Ken [illegible], Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. September 1993

Bacteria Growing

Introduction

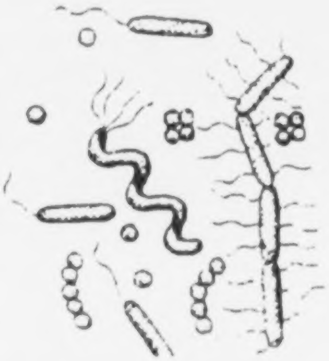
Recycling organic matter is an important task of soil organisms. Many organisms perform other tasks that also are important to agriculture. Most microorganisms need air, water, and food to thrive. These materials are best supplied in the top two feet of soil. Thus, most soil organisms live near the soil surface. Microorganisms -- mostly simple plants (flora) or animals (fauna) -- are so named because they are too small to be seen by the naked eye. Many categories of microorganisms inhabit the soil, but bacteria, simple one-celled organisms, are the soil's most abundant inhabitants. More than 100 million microorganisms may live in one teaspoon of soil.

Objective

Participants will be able to understand how inoculation affects the growth of plants.

Competencies

1. Describe the difference in growth in soybean plants of inoculated soil, and in soil that has not been inoculated.
2. Examine the root systems and note the differences.



Materials

1. Three containers suitable for growing soybean plants.
2. Soybean seed.
3. Soil taken from a local site.
4. *Rhizobium* bacteria to inoculate soybean seed.
5. Autoclave or pressure cooker to sterilize soil.
6. Pot labels.

Procedure

1. Collect enough soil from the local site to fill three containers suitable for growing soybean plants.
2. Sterilize enough soil for two containers, as well as the three containers.
   This can be accomplished by placing a couple of pounds of soil in a pressure cooker for an hour.
3. Label each container (sterile, natural, bacteria).
4. Fill the natural container with unsterilized soil. Fill the other two containers with the sterilized soil.

5. Plant three to four soybean seeds in the two containers with sterile soil and the one container with natural soil.
6. Inoculate the soybean seeds to be planted in the bacteria container with the correct Rhizobium bacteria.
7. Water each container thoroughly with the same amount of water at the same time and place each in a suitable growing area.
8. Observe the growth of the soybean plants, watering with the same amount of water, always at the same time.
9. Compare the plants' growth as they develop.
10. When the experiment is over (approximately 30 days), carefully wash soil off roots and note any differences between the three root systems.

Keep a notebook with your analysis of plant growth, making comparisons of the three containers.

Conclusions:

What are your conclusions about the value of bacteria in soybean production?

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992

Composting : Getting Those Microbes In Gear!!

Introduction

Gardeners know that composting is an excellent way to recycle dead plant materials and return them to the garden. Composting piles take advantage of the decomposition process, in which soil organisms such as nematodes, earthworms, and bacteria work to convert the plant material to humus. During this process, changes occur in both the physical and chemical properties of the material that is broken down. This conversion of plant material to humus is critical in soil development and in making nutrients available to plant roots.

Compost piles are easy to make and maintain, as will be demonstrated in this experiment.

Objective

Participants will be able to measure chemical, temperature, and material-related changes (due to biological processes) that occur when material is recycled in a compost pile.

Competencies

Don't keep us too dry or we won't work

1. Design, construct, and maintain a compost pile.
2. Evaluate the changes in the materials contained in a compost pile.
3. Calculate plant material and fertilizer needs, and apply the correct amount to the compost pile.

Materials

1. Compost material (grass clippings, leaves, straw, sawdust, hedge clippings, weeds, etc.) Table scraps such as vegetable peelings, fruit peelings, etc. can be included.
2. pH testing materials.
3. Soil thermometer.
4. Materials for measuring soil organic content.
5. 12-12-12 fertilizer.

Procedure

1. The frame for the compost pile can be constructed in one of two ways:
    a.) by digging a pit into the ground, or
    b.) by making a rectangular frame, using boards, wire, snowfence, etc.
2. Place eight to 12" of compost material in the frame (a mixture from the Materials list, item 1).
3. Cover this layer with the fertilizer, *using one quart of fertilizer for every three cubic yards of plant material* - *CALCULATE*

4 Make sure to thoroughly moisten this layer, then cover it with one to one-and-a-half inches of soil
5 Make a depression in the top to catch rainwater
6 Turn the pile once a month and water it down
7 Before turning the pile, record the temperature, pH, and organic content at the center of the pile Record your results

Discoveries

1 Describe any changes in the appearance of the materials
2 Which type of material decomposed first, and why?
3 Did the temperature change? Why, or why not?
4 How did the pH change? Was the change what you expected? Why, or why not?
5 Was an odor associated with the decomposition process, and, if so, could it come from the microorganisms? Explain

Conclusions

1 Define the following terms
  a.) Litter

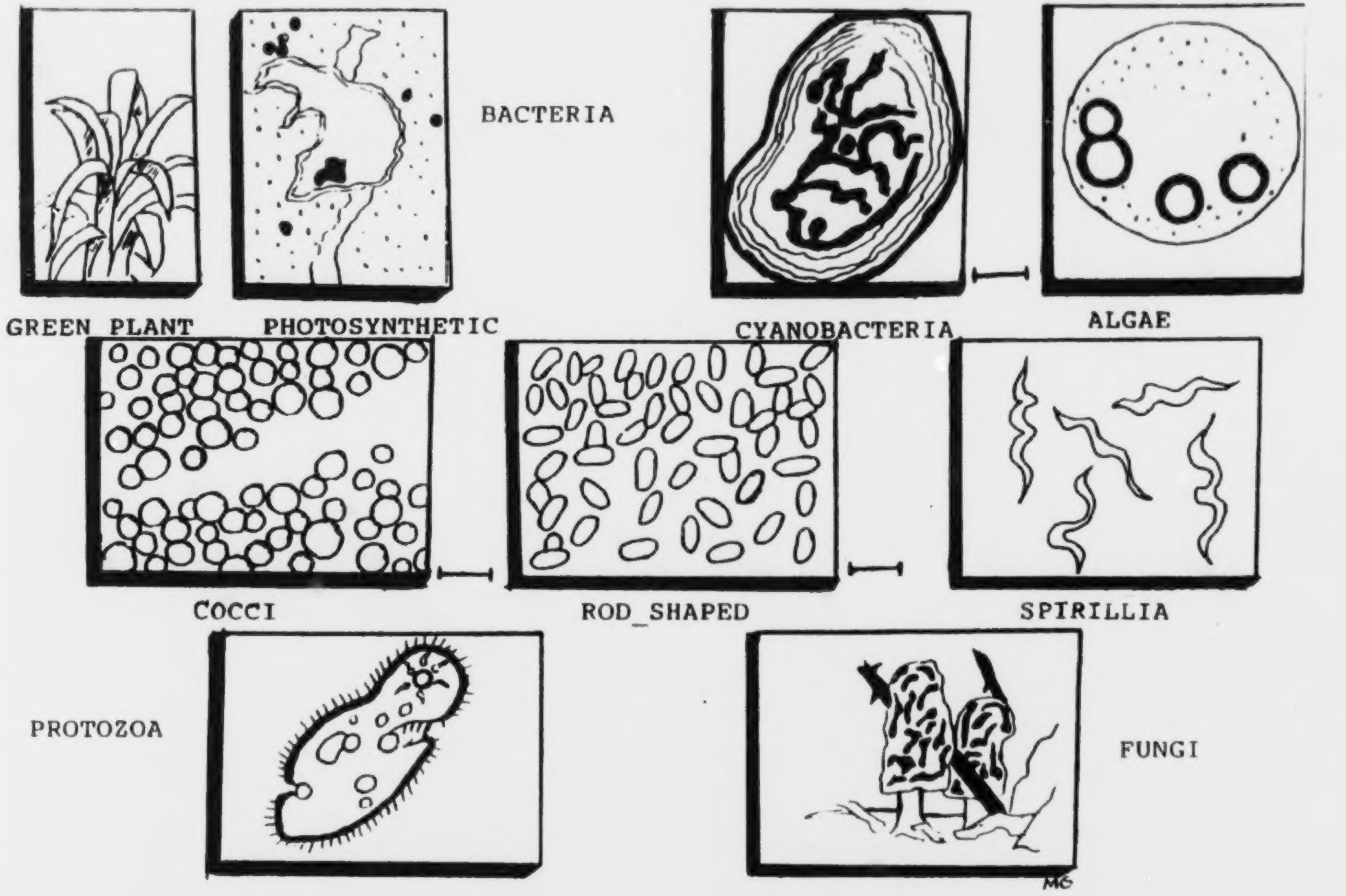
  b.) Fermentation

  c.) Humus

2 Does this experiment have any practical value for both the farm and city dwellers? If so, what?

Total conversion of a compost pile takes approximately one year. The recycled humus can be used by placing it on the school lawn or gardens. The compost pile could be kept in continuous use by adding new material and removing the humus.

Source Andrews, William A., Editor A Guide to the Study of Soil Ecology Prentice-Hall, Inc New Jersey 1973
Adapted by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa May 1994


BACTERIA
GREEN PLANT
PHOTOSYNTHETIC
CYANOBACTERIA
ALGAE
COCCI
ROD_SHAPED
SPIRILLIA
PROTOZOA
FUNGI
MG

Designed by Middy Gillespie, Iowa State University, Ames, Iowa April 1994

Teammates

Summary

√ Classification of bacteria can be accomplished in the following ways:

- ☞ Biochemical reactions
- ☞ Morphology (shape)
- ☞ Anaerobic
- ☞ Aerobic
- ☞ Heterotrophic
- ☞ Autotrophic

√ Bacteria are most active in the rhizosphere -- the area around the plant roots.

Unit II - d
Understanding the Beneficial Role of More Complex Soil Organisms

Introduction

Soil biology is a very complex ecosystem. Larger, more complex soil organisms play a major part in this soil ecosystem. They help break down organic matter, they kill harmful insects, and they help mix organic matter into the lower soil layers. This section will introduce various types of higher order soil organisms: soil insects and nematodes.

Objective

Participants will be able to: identify soil insects from given soil samples and make comparisons; identify characteristics of arthropods and learn the importance of microarthropods in the breakdown of organic matter; and investigate the role of the nematode in the soil and in plant growth.

Check out my more complex teammates

Competencies

1. Identify insects that are related to the soil ecosystem.
2. Define the role of insects in a soil ecosystem.
3. Analyze different soil ecosystems and determine the benefits of the insects that are identified.
4. Determine which arthropods are found in different kinds of organic matter.
5. Explain the function of nematodes in the soil.
6. Differentiate between beneficial and harmful nematodes.

Materials

1. Different soil types
2. Magnifying glasses
3. The game "Cootie", if possible
4. Refer to Lab materials

Information

INFO-MICRO-10 Marveling at the Macroworld
INFO-MICRO-11 Vocabulary Builder
INFO-MICRO-12 Arthropods: What are they?
INFO-MICRO-13 A Look at the Nematode

Activities

ACT-MICRO-18 Vocabulary Challenger
ACT-MICRO-19 Knowledge Builder

Laboratories

LAB-MICRO-9	What's at the Surface?
LAB-MICRO-10	Insect Populations in Fields at Different Residue Levels
LAB-MICRO-11	Sense of Touch
LAB-MICRO-12	The Hardest Workers in the Soil
LAB-MICRO-13	Discovering Arthropod Populations
LAB-MICRO-14	The Tiniest Threads

Visual Master

VM-MICRO-13	Nematode
VM-MICRO-14	Summary

Teaching Procedure

1. As an **Interest Approach**, provide samples of real soil insects for participants to examine. If this is not possible, use slides, overheads, or photos to stimulate the participants' interest. Ask participants if they can identify the insects. If they can, ask where they have been seen. Ask participants to compare and contrast the types of insects: analyze body parts and see which are alike and which are different. They also can identify insects using an identification book.

   Provide a list of soil insects, then ask more questions to promote discussion:
   What role do these insects play in the soil?
   For what purpose do they exist?
   Which of these insects are beneficial? Which are harmful?

   For another **Interest Approach**, have participants collect insects from under rocks or logs at home and bring them to class. Most of them should be arthropods. Have the participants examine them. Ask the following questions:

   Where were these insects found? Why do they exist there?
   What characteristics do these organisms share? Why?
   What function do they play in the soil?

2. Provide participants with a copy of **INFO MICRO-10** (Marveling at the Macroworld) for background information about the soil insects they may have identified in the interest approach.

3. Use **INFO-MICRO-11** (Vocabulary Builder) to review key terms for this unit.

4. Select any or all of the following laboratory activities relating to soil insects. They will help participants discover where insects are found, their function in the soil, and how they live.

   LAB-MICRO-9 (What's at the Surface?)
   Participants will find that the two types of traps will attract different organisms, even though they are placed in the same spot.

   LAB-MICRO-10 (Insect Populations in Fields at Different Residue Levels)
   Participants will investigate the number of insects found in various residues.

   LAB-MICRO-11 (Sense of Touch)
   Participants will discover that these insects are sensitive to different fabrics and textures.

   Q1 Can the wood lice sense the differences in the smoothness of the fabrics? Explain.

   A1 The wood lice do sense the differences and they know which fabric they prefer. This explains why they are found in certain environments.

Q2 What benefits do soil organisms gain from their sense of touch?

A2 Soil organisms benefit from this sense because they are in the dark most of the time and they can test the environment in which they live. Their sensitivity will guide them to favorable environments. They will be concentrated in places that have certain physical characteristics.

LAB-MICRO-12 (The Hardest Workers in the Soil)
Participant will take a closer look at the ant, and the role ants play in the soil

Q1 Do ants cause soil mixing? And if so, how is it important to soil tilth?

A1 Ants do mix the soil, and this mixing improves soil tilth by breaking up large clods of soil and increasing soil volume by adding air space. This improves water infiltration and provides a better environment for plant growth.

5 Use **ACT-MICRO-18** (Vocabulary Challenger) to review key terms for soil insects.

Across:
1. Pollination
5. Residue
6. Mixing
7. Diptera
8. Coleoptera
9. Caterpillar
12. Ecosystem

Down:
2. Nematodes
3. Burrows
4. Lady beetles
5. Rotifer
10. Aphids
11. Fauna

Arthropods are very visible soil insects, and in the next few activities, participants will take a closer look at them.

6 Use **INFO-MICRO- 12**(Arthropods: What Are They?) to provide background information about this particular type of soil insect.

7 Use **LAB-MICRO-13** (Discovering Arthropod Populations) to help participants calculate the number of arthropods in a given area.

Nematodes are in a class all their own, and even though they are microscopic, they have a big impact on soil and plants.

8 As an **Interest Approach**, use **VM-MICRO-13** (Nematode) and ask the following question. What do you know abut the soybean nematode? Consult your Extension Service.

9 Provide participants with a copy of **INFO-MICRO-13** (A Look at the Nematode) for background information. Ask participants to research the characteristics of beneficial nematodes.

10 Participants will be able to investigate the nematode further with **LAB-MICRO-14** (The Tiniest Threads). They will determine nematode populations and the soil types that favor nematodes.

11 Use **ACT-MICRO-19** (Knowledge Builder) to help participants learn key terms about arthropods and nematodes.

Q1 Match the following terms with their correct definitions.

A1
i Needle
e Predatory
o Mobile
m Nematode
l Decaying
r Exoskeleton
f Centipede
p Termite
c Turf
g Freeliving
k Puncture
q Parasitic
j Ringlike
h June
b Tubelike
d Arthropods
n Nerve cord
a Jointed

Q2 How would nematodes benefit agricultural crops?

A2 Some species of nematodes feed on other species. It may be possible to find a type of nematode that will feed on detrimental nematodes. It would benefit the crops by biologically controlling the detrimental nematodes. Crops would then stay healthy and vigorous because there would not be any root damage caused by puncture holes from harmful nematodes. There also would be less risk of infections and soil-borne diseases.

Q3 How do arthropods affect soil quality?

A3 Arthropods help in the breakdown of decaying organic matter, and help to convert it into nutrients plants can use. They affect the tilth of the soil because they do burrow in the soil, mixing it up and allowing air to enter the soil. This enhances soil quality.

12 Use **VM-MICRO-14** (Summary) to summarize Unit II-d.

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Marveling at the Macroworld

Have you ever been out in a field or garden and turned over a rock to see what crawled out? How about being in the woods and turning over a log? Many organisms make their homes in moist, dark places. **Ninety-five percent of all insects come in contact with the soil in at least one stage of their life cycle.** Many wasps, bees, and ants (Hymenoptera) live in the soil. Wasps are beneficial in two ways. 1) Wasps such as the Trichogramma control many species of caterpillar pests in many crops by laying their eggs inside the pest. When the wasps emerge from the egg, they kill the host pest. 2) Wasps also serve by creating burrows that aerate and enrich the soil with organic matter. Bees benefit soil fauna by burrowing into the soil, aerating and enriching it. They also pollinate many crops. Ants benefit soil fauna by mixing much organic matter into the soil. Ants and some termite species alter soil more than other organisms by tunnelling. Like wasps and bees, they also create burrows for aeration.

Many beetles (Coleoptera) live on or under the surface of the soil. **Some beetles, such as the seedcorn beetle, corn rootworm, and wireworm, are major pests to agricultural crops. Other beetles are beneficial in controlling certain pests. Lady beetles, ground beetles, and rove beetles all help control a large variety of pests. Four hundred species of lady beetles feed on aphids, scales, mites, and other insect eggs.**

Most beetles assist in breaking down humus. They also create burrows for aeration and water infiltration, and they enrich the soil with organic matter. June beetle larvae, whose white grubs are often found in the soil, are plant pests. They can injure crops and turf areas. Larvae lie in the soil and feed on plant roots.

Many flies (Diptera) are in direct contact with the soil during their larval stages. Many of these, such as craneflies and army worms, are very harmful to agricultural crops. Syrhid, flower, and hover flies prey on aphids during their larval stages.

My larger teammates
help me mix the soil

VOCABULARY BUILDER
Unit II - d

Arthropod - a group of soil organisms, invertebrate animals with jointed legs and a segmented body. Included are centipedes and millipedes

Coleoptera - the scientific name for the insect family of the beetle.

Exoskeleton - the hard, outer covering of an arthropod

Diptera - the scientific name for the insect family of the fly.

Hymenoptera - the scientific name for a family of insects that includes wasps, bees and ants

Nematodes - a group of small, worm-like animals which commonly inhabit soils and feed upon plant roots and other organisms.

Parasitic - this term describes organisms that need a host to survive. The host can be another organism or a plant.

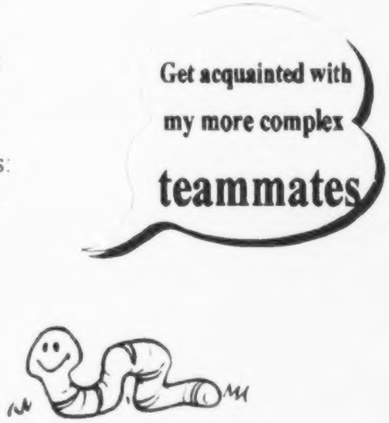
Predatory - this term describes organisms that feed on other organisms.

Residue - the material that is left over on the surface of the soil after a crop has been harvested, or the material remaining after the previous year's growth.

Saprophytic - a term that describes nematodes feeding on decaying organic matter.

Soil ecosystem - a system in which plants and animals inhabit the same location.

Soil Fauna - animal-related soil organisms: microarthropods, insects, and earthworms.


Get acquainted with my more complex teammates

Arthropods: What Are They?

Many of the organisms that live beneath rocks or logs in moist, dark places are called arthropods. Arthropods have special characteristics:

1. Each organism in this group has a body formed of a number of ringlike segments.

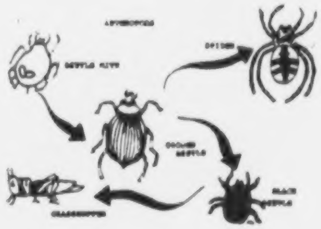
2. Arthropods have legs made up of jointed segments.

3. They have an outer covering of a hardened, horny material, called an exoskeleton (external skeleton).

4. The arrangement of body parts is such that they can be split down the middle into equal halves.

5. The nerve cord (similar to a spinal cord in vertebrates) is found in the lower part of the body.

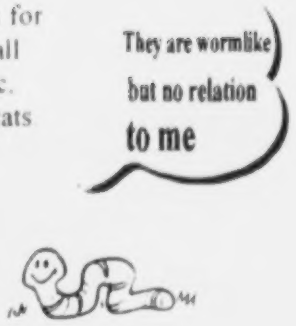
6. The heart is a simple tubelike structure found in the upper part of the body.



Examples of arthropods include ants, centipedes, millipedes, wood lice, springtails, and billbugs. Most of these arthropods feed on decaying organic matter, but some may feed on living plants and plant roots. Their behavior and their influence upon the ecosystem vary. Some arthropods take in soil particles with their food. Thousands of other insects inhabit the soil at one time or another during their life span. Only a few examples have been presented here.

A Look at the Nematode

The name nematode means "thread-like," which suits for these soil organisms well, because they resemble small pieces of fine thread. The nematode is a microscopic, eel-like worm. Nematodes exist in a variety of habitats. In fact, they occupy almost every major habitat in the world. About 2,000 species of nematodes inhabit the soil, and about half of these are known to be true soil species. They are the second most abundant organisms in the soil. They can be classified into three groups:


They are wormlike but no relation to me

1. A group that lives on plants (usually specific types of host plants).
2. A group that lives on other nematodes and other forms of soil life, such as bacteria and protozoa.
3. A group that lives on decaying organic matter, including dead bacteria and protozoa.

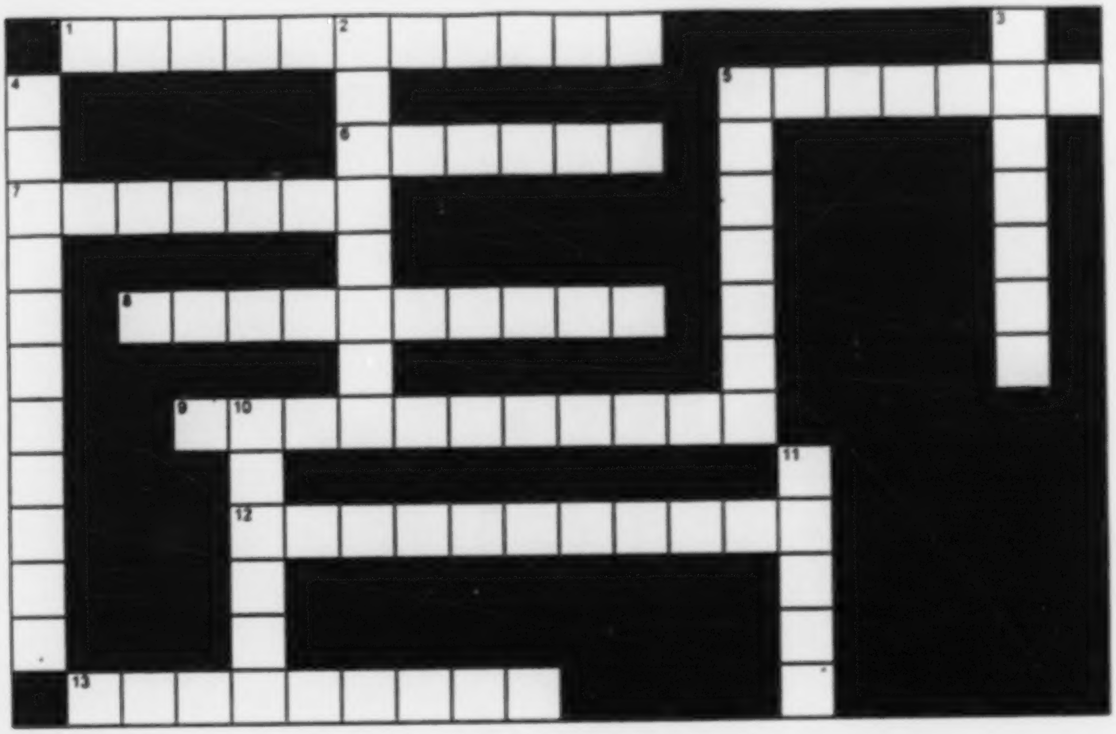
Some species of nematodes are very harmful to plants and other soil organisms, but some are beneficial species that feed on plant pests. Farmers are most concerned with parasitic types of nematodes. The nematodes that attack plants are far more important because of the damage they can do to agricultural crops. Members of this group usually spend their active life in some part of a plant. They infest plants by puncturing the plant root with their needle-like mouthparts. This causes the plant to lose its strength, which reduces yields. Other fungal or bacterial diseases can enter the plant through the tiny puncture wounds made by the nematodes. For that reason, infections by other soil-borne diseases often are related to nematode feeding. Most nematodes can be found feeding on microbes that exist in decaying organic matter. A few prey on other soil fauna, including other nematodes.

Many nematodes are free-living forms, which are very mobile and spend their time swimming or wriggling through films of water on soil particles. The smaller free-living forms feed on bacteria, small algae, and actinomycetes. They possess "teeth" for breaking up the small organisms on which they feed. Larger forms of nematodes are not as prominent, but are still important. They also have strong teeth that enable them to grasp and devour smaller nematodes and other worm-like organisms.

Soil nematodes tend to be located in the top five centimeters of the soil, and rarely are found below 10 centimeters. The smaller free-living forms that feed on microorganisms are found in the upper soil layers. The parasitic forms are found in the same areas, because they are feeding on plant roots while the predatory nematodes are feeding on the smaller nematodes.

Increased research has been done on nematodes in the last few decades. Information on the agriculturally important species is prevalent, but more studies must be made of the species as a whole.

Vocabulary Challenger - Unit II - d



ACROSS

1. Bees provide burrows in the soil and _____ of crops.
5. Material left on the soil after harvesting.
6. Ants are beneficial because they _____ organic matter in the soil.
7. The scientific name for the fly family.
8. The scientific name for the beetle family.
9. A pest that is controlled by wasp larvae.
12. The scientific name for the family that include wasps, bees, and ants.
13. A system in which plants and animals inhabit the same location.

DOWN

2. A small, worm-like soil organism that feeds on plant roots.
3. Wasps, bees, and ants provide aeration for the soil by making _____.
4. These soil insects eat aphids, scales, and mites.
5. An organism that spins around chasing bacteria.
10. Many flies eat these organisms in their larval stages.
11. Animal-related soil organisms such as earthworms.

Prepared by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. March 1994

Knowledge Builder
Unit II - d

1. Match the following terms with their correct definitions.

___ Needle
___ Predatory
___ Mobile
___ Nematode
___ Decaying
___ Exoskeleton
___ Centipede
___ Termite
___ Turf
___ Freeliving
___ Puncture
___ Parasitic
___ Ringlike
___ June
___ Tubelike
___ Arthropods
___ Nerve cord
___ Jointed

(a) This term describes an arthropod's legs.
(b) This term describes the heart of an arthropod.
(c) A type of ground cover that is damaged by white grubs.
(d) A group of soil organisms that includes millipedes, mites, wood lice, and billbugs.
(e) These nematodes eat other nematodes and soil organisms.
(f) A type of arthropod.
(g) This describes the form of nematode that can swim around.
(h) This beetle's larvae are serious plant pests.
(i) A nematode's teeth are similar to this.
(j) The segments of an arthropod are shaped like this.
(k) Bacteria and plant viruses can enter plant roots through this type of hole made by the nematode.
(l) Arthropods feed on ______ organic matter.
(m) Word meaning "thread-like".
(n) This is found in the lower part of an arthropod's body.
(o) Term describing freeliving nematodes.
(p) An arthropod known for tunnelling behavior.
(q) This type of nematode needs a host to survive.
(r) The hard, outer covering of an arthropod.

2. How would nematodes benefit agricultural crops?

3. How do nematodes and arthropods affect soil quality?

What's at the Surface?

Introduction

Many kinds of soil insects can be found on the soil surface. Earthworms are seen most often at the surface of the soil; what other types of organisms are found there? The types of organisms range from arthropods with hard-shelled skeletons to soft slugs. This exercise will show which types of soil organisms are found at the soil surface.

Objective

Participants will be able to collect and describe types of soil insects found at the soil surface at various sites.

We'll come to the surface after a rain

Competencies

1. Construct surface traps to catch different types of soil organisms.
2. Identify the soil organisms caught in the traps.
3. Follow directions correctly.

Materials

1. Several pieces of plate glass (30 x 20cm)
2. Resin
3. Several unpainted boards (2 x 30 x 20cm)

Procedure

1. Paint the resin on one side of each piece of glass.
2. After the resin gets sticky, place the glass (resin side up) in various locations (e.g., a lawn or grassy area, a garden, in the woods, etc.).
3. After 48 hours, check the traps and identify the organisms caught in the traps.
4. Place the boards in the same locations as the plate glass and leave them for two to three weeks.
5. Turn the boards over and identify the organisms under the boards.

This procedure can be repeated during wet or dry periods and during different seasons. Compare the results of each trial.

Discoveries

1. List the organisms found in each trap (record your results on the attached data sheet).

2. What are the characteristics of the organisms found in each trap?

Data Sheet - What's At the Surface?

Fill in the following background information; then, use the table below to record your observations.

Trap Locations: *#1* ______________________________
(Identify) *#2* ______________________________
#3 ______________________________
#4 ______________________________

Experiment Dates: Glass traps - *Initiated* __/__/__ *Completed* __/__/__
Board traps - *Initiated* __/__/__ *Completed* __/__/__

TRAP LOCATION		**TRAP TYPE**	
		Glass/Resin	**Board**
#1	List of Organisms		
	Comments		
#2	List of Organisms		
	Comments		
#3	List of Organisms		
	Comments		
#4	List of Organisms		
	Comments		

Source: Andrews, William A., Editor. A Guide to the Study of Soil Ecology. Prentice-Hall, Inc. New Jersey. 1973
Adapted by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1994

Insect Populations in Fields at Different Residue Levels

Higher populations of insects are found in fields in which there is more residue, i.e., plant material from the previous year's crop that remains on the soil surface. These insects help to recycle the residues into organic matter. This does not mean these fields will have more problems with pest damage than fields with less residue. In many cases, a field with higher residue will have a more natural ecosystem that keeps pest populations in check.

Objective

Participants will be able to capture and compare the number of soils insect found in certain soils with different amount of organic matter.

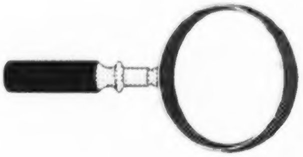
Try to identify my teammates

Competencies

1. Select sites and properly collect soil insects.
2. Identify the types of insects found in selected areas.

Materials

1. Four feet of rope
2. Five bags to hold soil and residue
3. Magnifying glass or stereoscope
4. Data sheet (one per group of three students)
5. Hand towel



Procedure

1. Select fields based on their percentage of **surface residue**. Five different fields will enable participants to make a good comparisons.
2. Group participants in sets of three persons.
3. Start out in the first field. Lay out the rope in a one foot square.
4. Have the group dig six inches into the soil inside the rope. Place soil and residue in a bag.
5. Repeat #3 and #4 for each of the five fields. Keep the samples separate to compare the number and types of insects found in each field.
6. Have participants sort through the soil and residue and collect any insects found. Place insects in a jar to be identified later.
7. Have participants identify the insects in the jars, count the number of each, and record on a data sheet.
8. Calculate the numbers of each insect per acre (no./sq.ft. x 43,560 sq.ft./acre = population/acre). Compare the fields and note any differences.

Adapted by Ken Wise, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. September 1993

Sense of Touch

Introduction

Most soil organisms spend their lives in total darkness. If they do come out of the soil, it is probably at night. They do not have a good sense of sight, but they have an excellent sense of touch, which is more important in the soil. This sense is essential when determining desirable conditions in which an organism must exist. The wood louse is an example of an organism that depends on its sense of touch. This experiment will show how wood lice react to different surfaces.

Objective

Participants will be able to determine which conditions are favorable/unfavorable for wood lice, as an example of an organism which depends on its sense of touch for survival.

Competencies

1. Explain how soil organisms benefit from their sense of touch.
2. Describe the behavior of an organism that depends on the sense of touch for survival.

We're in the dark most of the time

Materials

1. Two or three adult wood lice
2. Moist soil contained in a culture bottle
3. One to two Petri dishes
4. Paper and pencil
5. Stopwatch or watch with a second hand
6. Scissors
7. Different types of fabrics: pieces of waxed paper, unwaxed paper, blotting paper, flannel, wool, silk, cotton, etc.
8. Cloth or cellophane tape

Procedure

1. Trace around the bottom of the Petri dish with a pencil onto one of the fabrics chosen to be used in the experiment.
2. Cut out the outline of the Petri dish with the scissors.
3. Fold the circle in half and cut along the centerline to get two identical halves.
4. Do the same with all of the other types of fabrics being used.
5. Make a "test surface" by taping together segments of two different materials to make a complete circle.

6. Place the "test surface" in the Petri dish *lid* with the taped side down
7. The Petri dish *lid* should be on a desk surface.
8. Trace the Petri dish *bottom* on a piece of white paper
9. Place one wood louse in the center of the petri dish *lid*. and place the *bottom* within the sides of the lid
10. Draw on the white paper the path taken by the louse in a period of five minutes
11. Keep track of which side each fabric was on.
12. Replicate the experiment using different types of fabric

Discoveries

1. What surfaces do the wood lice prefer?

Conclusions

1. Can the wood lice sense the differences in the smoothness of the fabrics? Explain

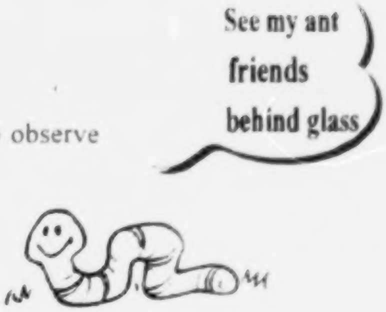
2. What benefits do soil organisms gain from their sense of touch?

Source: Andrews, William A., Editor. A Guide to the Study of Soil Ecology. Prentice-Hall, Inc. New Jersey 1973
Adapted by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1994

The Hardest Workers in the Soil

Introduction

Ants are important workers in the soil. Their burrowing increases soil volume, which increases soil tilth. This exercise will demonstrate how ant colonies work in the soil.


See my ant friends behind glass

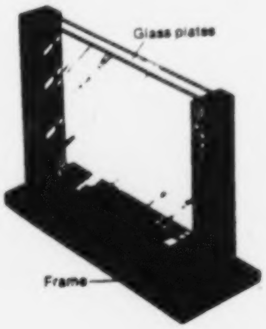
Objective

Participants will construct an apparatus that will be used to observe an ant colony. They will be able to demonstrate, observe, and understand how ants improve soil quality.

Competencies

1. Analyze the impact that ants have on the soil.
2. Follow directions correctly and construct an apparatus to contain ants.
3. Analyze changes in conditions due to ant activities.
4. Calculate and project the length of ant tunnels made in one day/one year.
5. Analyze ant work habits.

Materials



1. Two eight-inch square glass sheets, to slide vertically into the ends of the wooden frame,(placed about 1/4" apart, to serve as sides to the container)
2. Wooden frame for the base and ends of the apparatus, base - 1" x 2" - 10" long,ends - 1" x 2" - each 8" long, and glue or nails to attach the two ends to the base
3. Forty to fifty adult ants and the same number of larvae and pupae
4. Loose soil that can be easily worked by ants
5. Water and a tray
6. Tape and two sheets of black paper
7. A marker for the glass.

Procedure

1. With the marking pen, make a grid on one of the glass sheets, drawing each grid line one inch apart. The rows should be *lettered* from top to bottom (A-F), and the columns *numbered* from left to right (1-8), start the grid two inches down from the top of the glass to leave some "air space" for soil displacement (for an example grid, see the attached data sheet). The grid should cover the entire soil area.

2. Set up the apparatus (the wooden frame, with the glass sheets placed about 3/8" apart in grooves cut into the base and ends of the wooden frame).
3. Fill the soil chamber one half to two thirds full of soil.
4. Add the soil containing the ant colony (including ants, larvae, and pupae) fill to the top of the grid.

5. Pour water into the tray, and place the soil chamber apparatus in the water with at least eight inches around the outside. The water serves as a moat to insure that the ants won't escape.
6. Observe ant activity for 20 minutes, then cover the sides of the chamber with dark paper so the ants can work under normal, dark conditions.
7. Observe the ants again 24 hours later.

Variations: Conduct these variations one at a time and record the results to test the effects of different types of conditions.

1. Cut a hole in the black paper in a certain chamber.
2. Add water to one end of the apparatus so the soil will be damp to a depth of about 4".
3. Place food (syrup, for example) in a small container on the surface. Observe after 30-60 minutes.
4. Shine a bright light on the surface.
5. Place a rich mulch on the top, about three fourths of an inch thick.
6. Add "intruders" -- foreign ants -- to the surface.
7. Add other soil inhabitants.

Discoveries

1. Look at the change in soil conditions after the first day of activity.
2. Look at the tunnels and track their length (project length in feet or miles for one year).
3. Have soil levels changed?
4. Has soil volume changed? If so, calculate the changes.
5. Using the grids marked on the sides, locate the areas of most activity. Note the number and position of the larvae. Record any other miscellaneous information of importance.
6. Examine the apparatus every 24 hours. Note new chambers being built, how old chambers are being utilized, and the numbers of larvae and pupae.

Use the attached data sheet to record your observations.

Conclusions

1. Do ants cause soil mixing and, if so, how is it important to soil tilth?
2. What was observed in ant work habits?

Data Sheet - The Hardest Workers in the Soil

Source: Andrews, William A., Editor. A Guide to the Study of Soil Ecology. Prentice-Hall, Inc. 1973.
Adapted by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1994.

Fill in the following information, then, use the grid below to record your observations

Observation Date: ___/___/___
Time: _______

Comments -

1	2	3	4	5	6	7	8
A							
B							
C							
D							
E							
F							

Discovering Arthropod Populations

Introduction

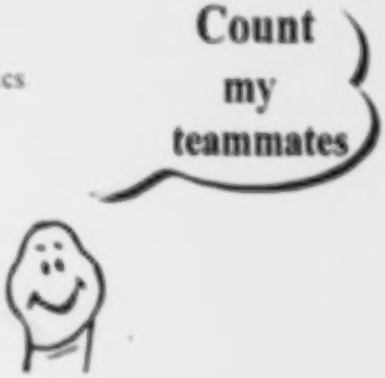
Arthropods are very busy insects that change soil structure. They can be seen readily and can be caught in order for participants to take a closer look at them.

Objective

Participants will be able to obtain a residue sample and conduct an experiment that will allow them to observe arthropods.

Competencies

1. Construct a Berlese funnel.
2. Identify arthropods according to their characteristics.



Materials

1. Small funnel
2. Light source
3. 100 ml beaker
4. Rubbing alcohol
5. Four feet of small diameter rope
6. Four wooden stakes
7. Two large plastic bags
8. Tissue or cloth to cover top of funnel
9. Microscope and slide
10. Eyedropper

Procedure

1. Identify two areas in which soil residue samples can be obtained -- this can be a field, garden, forest, etc. Each area of soil must have several inches deep.
2. Use the rope to construct a 12"x 12" square supported by four stakes.
3. Carefully remove all residue inside the square, being careful not to remove the soil.
4. Place each residue sample in a plastic bag. Label each bag with the location.
5. Construct a Berlese funnel.
6. Loosely fill the funnel with residue from the sample site.
7. Cover the top of the funnel with tissue or cloth so the organisms do not escape.
8. Position the top of the funnel under the light source.
9. Put 50ml of water in a 100ml beaker. (70% ethyl alcohol also can be used. if water is used, however, the arthropods will still be alive.)
10. Place the beaker under the opening of the funnel.

11 Leave the funnel under the light source for two days

12 As the arthropods fall into the beaker, collect, identify, and record them on the data table

13 Note that microarthropods can be seen, but are very small The careful use of an eyedropper to collect them from the beaker is best

14 Place the arthropods on a microscope slide and identify them using the lowest power Many of the small animals may drop out during the first 30 minutes, but some may take as long as two days

Adapted by Kim Wise, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa

Data Sheet - Discovering Arthropod Populations

Sample #1

Location of sample ______________________________ Date of sample ________________

Population per acre = Number of animals/ft^2 x 43,560ft^2/acre

Total population per acre in your sample

Kind of Arthropod	Number Found	Number per Acre

Sample #2

Location of sample ____________________ Date of sample ____________

Population per acre = Number of animals/ft^2 x 43,560ft^2/acre

Total population per acre in your sample

Kind of Arthropod	Number Found	Number per Acre

Microarthropods

Conclusions

The Tiniest Threads

Introduction

To the naked eye, nematodes look like tiny threads. They live in the water that surrounds soil particles, and are not easily removed from these particles. This lab will show what nematodes look like after they have been removed from soil particles.

Objective

Participants will be able to understand the importance of the relationship between nematodes and the soil.

Competencies

1. Assemble an apparatus to extract nematodes from soil samples from various soil sites.
2. Make microscope slides and observe nematodes under the microscope.
3. Identify the number of nematodes in a soil sample.

Materials

1. Two large funnels, preferably glass
2. Two 25-watt light bulbs
3. Rubber tubing
4. Two pinch clamps
5. Two 250 ml beakers
6. Two ring stands and rings
7. Two glass rods
8. Cheesecloth
9. Topsoil and subsoil samples of equal size
10. Microscope
11. Glass slides and cover slips

See my friends under a microscope

Procedure

1. Place each soil sample in a cheesecloth bag, and close the top tightly.
2. *Assemble the apparatus for each soil sample.*
    a.) Place a short segment of rubber tubing over the bottom opening of each funnel, with a clamp closing each of the rubber tubes. Suspend the two funnel apparatus over beakers placed at the base of the two ring stands. (Adjust the rings on the ring stand to support the two funnels above the beakers).
    b.) Place water in the funnels.
3. Suspend the bags of cheesecloth (containing the soil samples) into the water-filled funnels. Make sure the cheesecloth is submerged in water, but the bag should not touch the sides of the funnel. Make sure there is some clearance between the funnel wall and the bag.

4. Place the light bulb about four inches above the water's surface. Turn the light on and leave it for 24 hours.
5. Open the clamp and allow the water and any organisms it may contain to drain into the beaker.
6. Find the organisms in the water and mount them on a glass slide. Observe and identify them under a microscope.
7. Count the numbers of nematodes in each sample.

Conclusions

1. Why was the separation of nematodes from the soil possible?
2. Was there a difference in the number of nematodes in each sample? What does that indicate about the type of environment nematodes prefer?
3. Does the amount of organic matter in the soil affect the number of nematodes? Why?

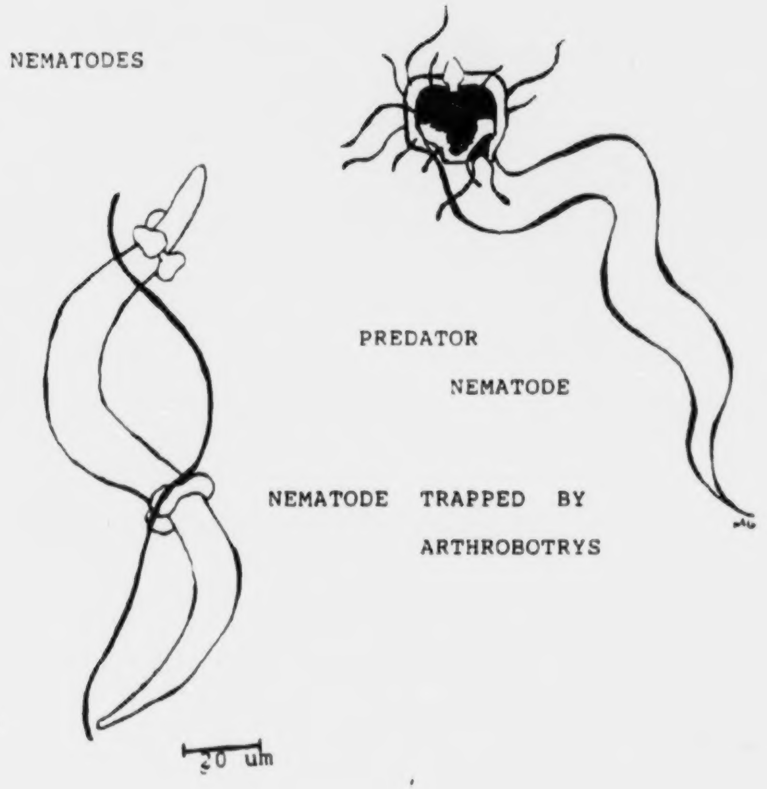
Extensions

This procedure can be repeated using different types of soils and comparing the upper layers.

Attempt this procedure during different times of the year, and observe how soil temperature affects nematode populations.

Source: Andrews, William, A., Editor. A Guide to the Study of Soil Ecology. Prentice-Hall, Inc. New Jersey. 1973
Adapted by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1994

Nematode


NEMATODES
PREDATOR
NEMATODE
NEMATODE TRAPPED BY
ARTHROBOTRYS
20 um

Designed by Mindy Gillespie, Iowa State University, Ames, Iowa. April 1994

Summary

√ Soil insects include the following species:

- ☞ Bees
- ☞ Wasps
- ☞ Beetles
- ☞ Flies
- ☞ Arthropods, which include:
  - ☻ Centipedes
  - ☻ Millipedes
  - ☻ Ants
  - ☻ Wood lice
  - ☻ Springtails

Prepared by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa April 1994

Summary

- √ Nematodes are microscopic, threadlike worms.
- √ Nematodes can be classified into three groups according to how they live:
    - ☞ On plants
    - ☞ On other soil organisms
    - ☞ On decaying organic matter
- √ Parasitic nematodes concern farmers because they affect agricultural crops.
- √ Soil nematodes live in the top five centimeters of soil.

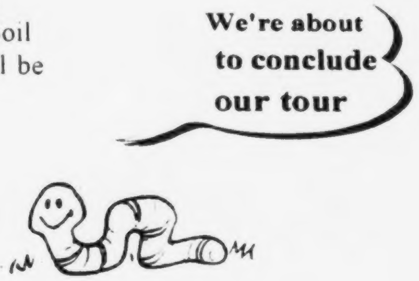
Unit II - e

Willy's Tour Comes to a Close

Application of Relationships Between Soil Organisms, Soil Health, and Plant Growth

Unit II has exposed participants to the incredible and dynamic aspects of a living soil. Participants have been introduced to various forms of soil life and how they affect soil health and plant growth.

This part of Unit II will provide participants with activities related to the subject matter found in previous sections. The activities will combine various aspects of the material provided in the Living Soil Curriculum and bring "Willy's Tour" to a close. Participants will be able to apply concepts used in earlier sections.


We're about to conclude our tour

The activities utilized in this section are:

Activities

ACT-MICRO-20 Soil Inhabitants as Filters

This activity pulls together concepts about soil health, good soil characteristics, and the need for bacteria and fungi in the cycling of nutrients. Participants should be able to prepare a short report, poem, song, or drawing to describe their perceptions of the plant-animal-soil relationship.

ACT-MICRO-21 Microbe Clean-up Crews

This activity applies what has been learned about microbes. The information provided shows how crop residues have been used to promote microbial growth, in order to clean up leaking underground petroleum tanks. This will promote a discussion about the uses of microbes and their benefits to the environment and society.

ACT-MICRO-22 Structure of Topsoil (post activity)

This activity has been used in Unit II-a as a pre-activity to test participant's perceptions of soil structure. It is used again in order to see if their perceptions have changed.

ACT-MICRO-23 Group Discussions

Participants are presented with an two scenarios in which they will need to discuss the pros and cons of the situations presented

Laboratories

LAB-MICRO-15 Soil to Soil

By using this lab, participants will see how different materials decompose and turn into material that can be added to the soil for use by plants. It also illustrates the activities of various soil organisms in the decomposition process.

LAB-MICRO-16 A Look into the Live Recycling Plant

The role of bacteria and fungi in the recycling of plant and animal materials is illustrated in this lab. It applies what was learned in earlier sections of Unit II. Comparisons can be made of different materials and soil types.

LAB-MICRO-17 How Earthworms Change the Soil

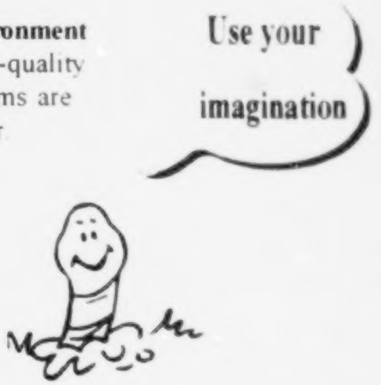
This lab reinforces the material presented in Unit I. Earthworms are essential to recycling of residues and improving soil health. This illustrates how earthworms work in the soil and continually improve it.

As Willy's Tour comes to an end, "Living Soil BINGO" has been developed to help participants remember all they have learned in all of Unit II. It is the final activity of the unit, and is a fun way to end the tour.

Soil Inhabitants As Filters

Soil is the "stomach" of the earth and fulfills the saying "ashes to ashes and dust to dust". Without the living soil organism, a "consumer and decomposer" to release fixed carbon, the atmosphere would be depleted of carbon dioxide, then life would cease and the life cycle would stop.

Soil and its inhabitants (soil organisms) act as filters and protect the environment by immobilizing and degrading wastes, chemicals, and pollutants. Higher-quality soils that contain high numbers and a wide range of different soil organisms are best at filtering out pollutants that otherwise might leach into groundwater.



Characteristics of a good soil are:

1. Enough depth for a good plant root system.
2. Granular composition, providing permeability for water and oxygen.
3. Active microorganisms to break down organic matter and pollutants.
4. Water and nutrient storage capacity so plants and "underground livestock" get their essential food and water.

The carbon-nitrogen ratio in soil organic matter is an important factor in a number of ways, for example:

* **Competition for available nitrogen results when residues having a high C:N ratio are added to soils.** For instance, when organic matter with a wide C:N ratio (say, 50:1) is incorporated into the soil under conditions supporting vigorous digestion, it causes bacteria and fungi to multiply, creating large quantities of carbon dioxide (CO_2). During this time, nitrate nitrogen practically disappears from the soil, because microbes demand this element to build their tissues. **For the time being, little or no nitrogen is in a form available to higher plants.** As the organic matter is recycled through microbial action, the C:N ratio of the plant material decreases, because carbon is being lost in CO_2, and nitrogen (as nitrates) is converted for higher plant use or is leached into groundwater.

After reading and thinking about the soil environment described above, prepare a short report, poem, song, or work of art describing your perception of this plant-animal-soil relationship.

Prepared by Eldon Weber, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. April 1994

Microbe Cleanup Crews

Soybean hulls are home to microbial cleanup crews. Soybean hulls provide a stable, suitable environment for microbes. In the Center for Crops Utilization Research at Iowa State University, researchers are encouraged by early studies that show soybean hulls may be a natural cleanser of oil and fuel spills. Petroleum products are leaking from underground storage tanks at an estimated 3,500 sites in Iowa. Soybean hulls may hasten the cleanup process by absorbing petroleum from the soil, allowing microbes to get at it more quickly. The hulls also may fortify microbes with essential nutrients. This research project is supported by the Iowa Soybean Promotion Board.

1. What does this technology mean to the farmer and to society in general?

2. Develop a microbe cleanup experiment comparing a control site to a site using soybean hulls. Consider using the same type of soil in the comparison, preferably one that is lower in organic matter and has a low population of microbes. (Use appropriate safety measures when handling petroleum products.)

Prepared by Eldon Weber, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. April 1994

Structure of Topsoil

Plant and animal life greatly influence the processes of soil formation. The "structure" of a soil is defined as "the arrangement of its parts" -- the way the particles of soil are put together. Soil loses its structure after being plowed continuously without the addition of organic matter. It has a tendency to run together when wet with water. We speak of good tilth, meaning the ease with which land responds to cultivation. Soil organisms recycle plant and animal residues into soil organic matter. The activities and by-products of soil life improve and develop the color and physical structure of topsoil. The work of microbes keeps the soil loose and crumbly, allowing water and air to penetrate to become available for plant roots.

Single-grain structure is a soil condition in which grains of soil exist independently. The grains are loose, not held together. *This is an undesirable condition.* **Granular structure** is a condition in which the soil particles are held together in small lumps which resemble bread crumbs in shape and porosity. *This is a desirable condition.* A dark topsoil indicates that living matter has grown and perished on the land and has been returned to the soil in the form of organic matter.

1. Describe the role that soil organisms play in the development of a dark-colored, granular-structured soil.

2. Describe what occurs to soil structure, color, and organisms when soil is plowed continuously with little or no organic matter added to the soil.

3. Draw two pictures: Imagine looking at the following with a powerful microscope. Be creative!!
   a) A magnified version of soil particles and organisms in single-grained structured soils with little organic matter.
   b) Another version of a granular-structured soil with lots of organic matter.

Prepared by Eldon Weber, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. April 1994

Group Discussions

CAN NEMATODES BE SPRAYED ON CORN TO CONTROL PESTS?

Beneficial nematodes are genetically different from the soybean cyst nematode and other plant parasitic nematodes. The helpful worms do not feed on plants. Their targets are the immature stages of harmful insects. It appears that beneficial nematodes can be applied in a band by a sprayer or they can be applied through water in an irrigation system. Once applied water is needed to move the organisms underground where they seek and destroy the immature stages (larvae and pupae) of soil dwelling insects. Their favorite targets are grubs, cutworms, root weevils and fleas. According to Greg Tylka, Plant Pathologist, Iowa State University, there are no adverse effects, no human health concerns and no toxicity in this technology. This technology could be available to Midwest corn growers as soon as 1995. (Joyce Vogelman, *Insects deployed to control crop pests.* **Iowa Farmer Today,** May 21, 1994)

Group Discussion:
One advantage of using this technology is that one application of this natural pest control may replace two to three pounds of insecticide per acre.
Disadvantages are:
1) irrigation is needed to provide enough water to work the nematodes down in the soil, as nematodes are sensitive to drying out and to sunlight.
2) if nematodes come in contact with beneficial insects, they may eat them too. However, most beneficial insects don't have their larval stage in the soil, while pest insects do.
Weigh the pros and cons and present your recommendations.

LIVESTOCK WASTE TRANSFORMED TO SOIL TREATMENT THROUGH MICROBES

A California company is transforming cow manure into a potting soil ingredient. The process involves treating the raw manure with a bacteria in large digesting tanks, where it is partially decomposed in an oxygen-free environment. The decomposition heats the waste to a temperature of 131 degrees, killing any disease-bearing microbes it might contain. The digested slurry is then separated into solid and liquid portions. The solid matter, which resembles a dark peat moss is laid out in rows to mature into a potting soil ingredient. As it cures, secondary decomposition kills any weed seeds the cow has ingested and even fosters new microbes that can rejuvenate poor topsoil. This process has also been used in Israel and Italy. Research has found that not only did the material perform well as a soil ingredient, it also contained beneficial microbes that controlled fungus and other diseases in potted plants, reducing the need for chemical treatments. (Tom Schmitz, *Growing money from cow manure.* **Des Moines Sunday Register**, June 5, 1994)

Group Discussion: It's obvious what the advantages are in this technology but what are the disadvantages? Does this have promise in our state?

From Soil to Soil?

Soil is a loose formation of weathered rock mixed with animal and plant organic material capable of developing and supporting life.

1 What is the significance of the word "developing" in this definition of soil?

2 Remember the food you ate at your last meal, and trace it back to the soil

3 **ORGANIC DIGESTER**

Use two-liter plastic beverage bottles (with the bottoms cut out) as columns for your organic matter digester. Attach a piece of mesh fabric (old pantyhose work well) over the open caps with a rubber band. Cut off other two-liter bottles for the base. Suspend the first cut-off bottles neck down into the bases of the other bottles. The bases hold the columns upright and collect any excess water that percolates through the organic matter.

Using any of the following materials, experiment with the value of microorganisms in recycling the material you place in the columns (leaves, crop residue, garden residue, etc.).

a. Weigh the same amount of materials for both columns on a postal scale.
b. In one of the columns, add about a half cup of garden soil.
c. Pour equal amounts of pond water or rainwater into each column. Add more water if needed until about a half a cup drips into the base. Keep materials wet for a few days. Before you begin, document your expectations for this experiment.
d. Analyze and compare the materials after a few days. How much of the material was converted in the two columns? Why the difference? Can you see any live organisms in the column with the soil mixture? How did the results vary from your expectations?

How can you apply what you learned in this experiment to technology to improve the environment in the future? How does it relate to sanitary landfills?

Think of other versions of this experiment. For instance, the microorganisms need oxygen. Does controlling the air in the columns influence the rate at which the microorganisms decompose the material? What is the effect of varying the amounts of water?

A Look Into the Live Recycling Plant

Introduction

Soil organisms recycle residues and add essential nutrients to the soil. Bacteria and fungi carry out the recycling process by breaking down materials such as crop residue, garden residue, leaves, etc. Such materials do not decompose at the same rate; the rate depends on the composition of the materials and the soil in which they are found.

Objective

Participants will be able to identify factors that affect the recycling of plant materials.

Competencies

1. Understand the process of nutrient recycling.
2. Analyze experimental observations and describe factors that encourage or limit the breakdown of residues.
3. Compare the rates of decomposition of plant vs.animal matter using different soil environments.

Materials

1. Sand
2. Soil rich in organic matter
3. Gravel
4. Dead plant material: grass, leaves, etc.
5. Dead animal material #1: table scraps of meat
6. Dead animal material #2: dead insects
7. Natural cloth, made of wool or cotton
8. Synthetic cloth, made of polyester or nylon
9. Fragments of a Styrofoam$^{(TM)}$ cup
10. Twelve two-inch diameter clay flowerpots
11. Four one-and-a-half inch petri dishes with lids
12. A large tray, about 12" x 10" x 2"

Watch our
inner space
magic

Procedure

1. In the base of each pot, place a small amount of gravel.
2. Fill half of the pots with packed sand, the other half with soil rich in organic matter. The pots should be filled up to one inch from the top.
3. Put dead plant material on one pot filled with sand, and on a pot filled with rich soil.

4. Use a Petri dish or lid to cover the material. Press the dish lightly into the soil.
5. Repeat steps 3 and 4 using the other five material samples.
6. Place all the pots on the tray, and add water to soak each pot's top to a depth of an inch and a half. This depth must be maintained throughout the observation period.
7. The tray holding the pots should be kept in a darkened area at room temperature.
8. Observe the pots every week for up to eight weeks until changes become obvious. Test the strength of the cloth fibers as time goes on. Record your results on the attached data sheet.

Discoveries

1. Which materials do not change during the observation period?
2. Which materials are decomposed more quickly?
3. In comparing dead plant and animal materials in the sand vs. the rich soil environment, does the rate of decomposition differ between the two soil environments?
4. Do you notice a difference in the decomposition rate of the dead plant vs. dead animal materials?

Conclusions

1. How does the soil type affect the rate of decomposition? Why?
2. How does this exercise relate to soil conditions in farming or gardening?
3. How do the findings in this exercise relate to sustainable agriculture or a productive garden?

Source: Andrews, William, A., Editor. A Guide to the Study of Soil Ecology. Prentice-Hall, Inc. New Jersey. 1973
Adapted by Dawn Hildebrandt, Department of Agricultural Education, Iowa State University, Ames, Iowa. May 1994

Data Sheet - A Look Into the Live Recycling Plant

Use the table below to record your weekly observations

POT CONTENT/ MATERIAL	OBSERVATIONS							
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Sand Dead Plant								
Sand Dead Animal #1								
Sand Dead Animal #2								
Sand Natural Cloth								
Sand Synthetic Cloth								
Sand Styrofoam								
Soil Dead Plant								
Soil Dead Animal #1								
Soil Dead Animal #2								
Soil Natural Cloth								
Soil Synthetic Cloth								
Soil Styrofoam								

How Earthworms Change the Soil

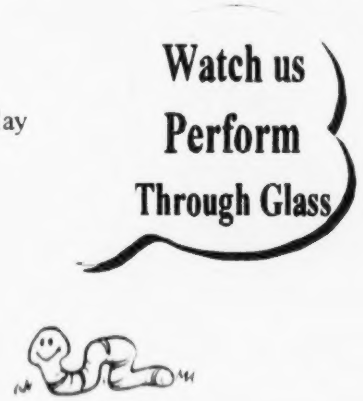
Introduction

Earthworms not only improve the soil by improving the soil structure, they can increase the total volume of the soil by as much as 20 percent!! How do they accomplish this? In this lab, the effects of the behavior of earthworms on the soil will be identified. These behaviors include tunneling, cast forming (the piling of waste material at the entrance to a burrow), soil mixing, and processing plant residues into usable forms.

Objective

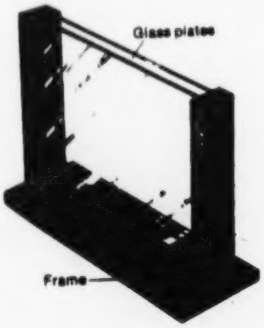
Through an experiment with live earthworms, participants will be able to identify earthworm behaviors that change the soil.

Competencies



1. Construct an apparatus to contain the earthworms.
2. Observe earthworm activity and define the role earthworms play in changing the soil.
3. Calculate changes in soil volume due to earthworm activity.
4. Describe soil conditions preferable for earthworms.
5. Calculate and project the length of earthworm tunnels in one year's time.
6. Analyze surface litter changes due to soil organisms.

Material



1. Two glass sheets, 8" x 8", to slide vertically into the ends of the wooden frame (placed about 3/4 " apart, to serve as the sides to the container)
2. Wooden frame for the base and ends of the apparatus, base - 1" x 2" - 10" long,
   ends - 1" x 2" - each 8" long, and glue or nails to attach the two ends to the base
3. One or more earthworms
4. Three or more soil samples (use samples with different colors, one that has lots of organic matter, and one with fine clay)
5. A few partially decayed leaves (any kind but oak)
6. A small piece of wire screen and weights
7. A marker for the glass.

Procedure

1. Set up the apparatus (the wooden frame, with the glass sheets placed about 3/4" apart in grooves cut into the base and ends of the wooden frame).
2. Moisten the soils that will be used (they should not be wet, only moist).
3. The first layer of soil in the bottom of the apparatus should be 2" to 4" deep, followed by a layer of clay (2" to 4" deep) on top of the first layer.
4. Continue adding different soil layers. Try to use contrasting colors in adjacent layers so they can be identified later.
5. Place a 2 1/2" layer of soil rich in organic matter across the top surface. Leave a 4" airspace at the top of the glass panels.
6. Draw a line on the glass to show the upper surface of the top soil layer.
7. Place a few leaves on the surface.
8. Place a worm in the apparatus.
9. Place the wire screen on top of the apparatus to prevent the worm from escaping. The screen may be held in place with weights.
10. Observe the earthworm's activity for 10-20 minutes and record its behavior.
11. Put the apparatus in a dark environment for 24 hours and then record any changes in the upper soil level.

Discoveries

1. Does soil volume change? Calculate any changes.
2. Look at the tunnels and trace their length.
3. How much tunneling would occur in one year change based on the length of tunnels made in one day?
4. Do the soil levels change- are they still in layers? If not, why?
5. How much tunneling is done in each layer? Does the amount vary with soil type?
6. Has the leaf litter on the surface changed?

This experiment can be continued if so desired; make sure that the soil is moist and the apparatus is in the dark.

Conclusions

1. Why is the mixing of the soil from one layer to another important?
2. If soil volume is increased by earthworm activity, is there an upper limit to the amount of the increase?
3. Where will the soil volume be increased -- will it occur in the upper or lower layers? Why?

Source: Andrews, William, A. A Guide to the Study of Soil Ecology. Prentice-Hall, Inc. New Jersey, 1973.
Adapted by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1994.

LIVING SOIL BINGO

Introduction

This activity is designed to provide a fun, comprehensive review of Unit II. It includes all of the terms included in the "Vocabulary Builder" information sheets. They are listed on the following page.

Have fun with us

Materials

Word list(s) for participants - without definitions
Word list(s) for facilitators - with definitions
A BINGO grid for each participant
Space markers - pieces of corn, or beans to mark the spaces

Directions

1. Provide participants with a copy of the BINGO grid, and a list of vocabulary words (without definitions) that will be used for the review. Twenty five words will be needed to fill the grid. The word list is longer than 25 words, so chose the word list(s) that are relevant to the sections used in Unit II.

2. Have the participants fill the blank spaces in the grid with the vocabulary words. Encourage them to place the words in any order on the grid.

3. Choose the word list(s) with the definitions that match the word list(s) given to the participants. They can be copied, cut apart, folded, and placed in a box.

4. The facilitator or a volunteer should draw from the box one piece of paper at a time. Read the definition (not the word!) and allow participants to decide which word matches the definition. They should mark the space containing the appropriate word with a piece of corn.

5. Continue reading definitions until a participant calls "BINGO". To have BINGO means that a participant has filled a straight line across, down, or diagonal with corn pieces. Have that person read the words and determine if they are correct. Facilitators should determine any "prizes" to be given at that time.

Notes:

- Continue playing as long as time permits.
- Any of the words can be used, but in combinations of 25 only.
- Vocabulary terms from different sections can be combined.
- Use different sets of words.
- Play as many times as necessary to review all terms.

"Living Soil BINGO" created by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa
June 1994

LIVING SOIL BINGO

"Living Soil BINGO" created by Dawn Hildebrandt, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa
June 1994

Vocabulary Word List - Facilitator

Unit II-a

Actinomycetes - group of microorganisms, intermediate between bacteria and fungi that are active in decomposing and responsible for the earthy smell of soil.

Aggregate - Lumps of various sizes formed by soil particles sticking together.

ARS - Agricultural Research Service

Bacteria - Most numerous, extremely small, single cell organisms. Some bacteria provide a mucus that binds soil particles together.

Fungi - A group of larger organisms that lack chlorophyll and may be linked together in long filaments called hyphae that help decompose organic matter.

Macrofauna - the largest animal related soil organisms -- includes burrowing animals such as the mole and pocket gopher.

Mesofauna - middle sized animal related soil organisms -- includes earthworms and soil insects such as arthropods, ants, termites, beetles, et.

Microbes (microorganisms) - Living creatures so small they can only be seen through a microscope (bacteria, fungi, actinomycetes).

Microfauna - the smallest animal related soil organisms -- microscopic organisms such as nematodes, bacteria and fungi.

Midden - The castings of earthworms which serve as a lid to their burrows.

Residue - The plant material left on the soil surface after a crop has been harvested.

Rotifer - A microscopic organism whose mouth looks like two rapidly revolving wheels.

Soil Ecosystem - A system in which plants and animals inhabit the same location.

Soil Organisms - Living creatures -- earthworms, microorganisms, and insects -- that live in the soil.

Soil Structure - The grouping or arrangement of soil particles

Soil Tilth - The "fitness" of a soil for cultivation. How a soil's physical properties affect it's capacity to support plant growth.

Unit II - b

Cellulose, hemicellulose, lignin - the major components found in many plant materials

Flagellate Fungi - found in water and soil; move around with a tail-like structure

Heterotroph - a class of organisms that depend on organic matter supplied by other sources. they do not produce their own food.

Higher Fungi - help in rotting wood, leaves, and crop residue in cool, moist areas

Hyphae - the branched filaments that make the weblike body of fungi

Imperfect Fungi - fungi that reproduce by asexual means

Mycorrhizae - the beneficial relationship between fungi and plant roots.

Organotroph - a class of organisms that decompose organic matter, fungi are classified into this group

Slime Molds - found in cool, moist places; process decaying vegetation into nutrients plants can use

Sugar Fungi - break down carbohydrates for plants to use.

Symbiosis - two organisms living in close association with one another. Fungi and plants have a mutually beneficial relationship.

Unit II - c

Aerobic (aerobe) - bacteria that require oxygen to live.

Anaerobic (anaerobe) - bacteria that live without oxygen.

Bacteria - single-celled organisms that break down substances plants can use.

Autotroph - bacteria that get energy from elements in the atmosphere.

Heterotroph - bacteria that are decomposers and get energy from carbon.

Inoculation - the introduction of nodule-forming bacteria into the soil, especially for nitrogen fixation.

Nitrogen fixation - the process of converting atmospheric nitrogen into forms plants can use.

Rhizobium **-** a species of nitrogen-fixing bacteria that depends on the root nodules of legumes to survive

Rhizosphere - the zone immediately surrounding plant root; the most active site for bacteria

Unit II - d

Arthropod - a group of soil organisms -- invertebrate animals with jointed legs and a segmented body. Included are centipedes and millipedes.

Coleoptera - The scientific name for the insect family of the beetle.

Exoskeleton - the hard, outer covering of an arthropod

Diptera - The scientific name for the insect family of the fly.

Hymenoptera - The scientific name for a family of insects that includes wasps, bees and ants

Nematodes - A group of small worm-like animals which commonly inhabit soils and feed upon plant roots and other organisms.

Parasitic - This term describes organisms that need a host to survive. The host can be another organism or a plant.

Predatory - This term describes organisms that feed on other organisms.

Residue - The material that is left over on the surface of the soil after a crop has been harvested or the remaining material following the previous year's growth.

Saprophytic - A term used when nematodes feed on decaying organic matter.

Soil Ecosystem - A system in which plants and animals inhabit the same location.

Soil Fauna - Animal related soil organisms -- microarthropods, insects and earthworms

Vocabulary Word List - Participant

Unit II-a

- Actinomycetes
- Aggregate
- ARS
- Bacteria
- Fungi
- Macrofauna
- Mesofauna
- Microbes
- Microfauna
- Midden
- Residue
- Rotifer
- Soil Ecosystem
- Soil Organisms
- Soil Structure
- Soil Tilth

Unit II - b

- Cellulose, hemicellulose, lignin
- Flagellate Fungi
- Heterotroph
- Higher Fungi
- Hyphae
- Imperfect Fungi
- Mycorrhizae
- Organotrophs
- Slime Molds
- Sugar Fungi
- Symbiosis

Unit II - c

- Aerobic (aerobe)
- Anaerobic (anaerobe)
- Bacteria
- Autotroph
- Heterotroph
- Inoculation
- Nitrogen fixation
- Rhizobium
- Rhizosphere

Unit II - d

- Arthropod
- Coleoptera
- Exoskeleton
- Diptera
- Hymenoptera
- Nematodes
- Parasitic
- Predatory
- Residue
- Saphropytic
- Soil Ecosystem
- Soil Fauna

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